THE PRACTICAL SENIOR TEACHER

GOVERNMENT BUILDINGS, WHITEHALL, AS VIEWED FROM ST. JAMES'S PARK, LONDON

Reproduced by courtesy of the artist, Leonard Richmond, R.O.I., R.B.A.

THE PRACTICAL SENIOR TEACHER

A GUIDE TO THE MOST MODERN METHODS OF TEACHING
IN SENIOR SCHOOLS

CONTRIBUTED BY LEADING AUTHORITIES IN EVERY BRANCH
OF SENIOR EDUCATION, WITH NUMEROUS ILLUSTRATIONS,
SCHEMES OF WORK, AND PRACTICAL SUGGESTIONS

Edited by F. F. POTTER, M.A., B.Sc.

DIRECTOR OF EDUCATION FOR THE COUNTY OF CHESHIRE; FORMERLY H.M. INSPECTOR OF SCHOOLS;
AUTHOR OF "COMMON-SENSE ENGLISH," "COMMON-SENSE ARITHMETIC," ETC.

Associate Editor: G. M. PLACE

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(By F. F. Potter, M.A., B.Sc.)

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WHITEHALL, THE HOME OF NATIONAL STATISTICS . . . *Frontispiece*

LINCOLN'S INN . . . . *Facing Page* 118

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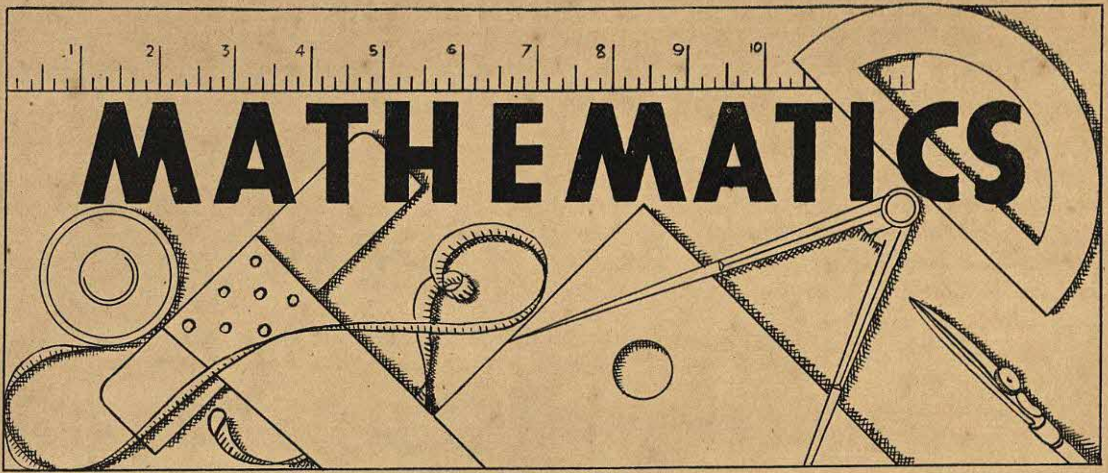
TYPICAL GRAPHS FOR INTERPRETATION (MATHEMATICS)

GEOLOGY: "THE STORY OF THE ROCKS"

FIRST AID

SCIENCE: PLANT AND ANIMAL FOODS

BIOLOGY: "THE PAGEANT OF THE SEASONS"



MATHEMATICS

THE teaching of Arithmetic and Elementary Mathematics to the Senior pupils in Elementary Schools has received very considerable attention during the post-war years. Criticism of the traditional treatment, on the whole, has been hostile, and has paradoxically followed two apparently opposite directions, for teachers have been told, on the one hand, that they are teaching far too much, and on the other that they are not teaching enough. Upholders of the conservative view maintain that the average syllabus is far too ambitious; that teachers, in their search for novel methods and applications, are overlooking the essentials of speed and accuracy in the fundamentals; and that accordingly the attention of all teachers should be concentrated upon fewer topics, and upon accuracy and a reliability in a few essential operations. Those who take a somewhat more liberal view of the subject would criticize, not so much the *accuracy* achieved, as the narrow range of topics attempted, and accordingly these critics ask for a wider and more mathematical approach to the subject—demanding syllabuses which include far less of the old-fashioned arithmetic, and far more of the developments of general elementary mathematics. This is the attitude developed in the "Hadow" *Report on the Education of the Adolescent.* Thus we read (pages 214 *et seq.*)—

> There seems to be general agreement that the subject of arithmetic as taught to-day, not only in primary but in other types of schools, is in need of considerable improvement, in regard to both choice of material and the use made of it. Arithmetic has been too long dominated by the traditional utilitarian value of the subject. It has been and still is frequently regarded solely as a "bread and butter" subject, providing the necessary facility and accuracy in such arithmetical work as will be required by the pupil in his after life. But the amount of this indispensable arithmetical knowledge, while of considerable importance, is in reality comparatively small, and would not in itself justify the time given to the subject. It has, however, in its presentation in schools, been added to and overlaid by matter which is often without meaning to the child and is seldom of value to him in after life. On the other hand, our modern industrial system with its complex ramifications, and the part played by science in the modern civilized community make greater demands upon the mathematical knowledge of the ordinary citizen. The scientific and engineering inventions of the modern world, motors, aeroplanes, wireless telephony, and the like, all require, even for a superficial understanding of them, some knowledge of mathematical principles and their applications. Civic, national, and even international finance, closely associated as they are with our daily existence, require for an intelligent comprehension of them an increasing amount of mathematical knowledge.
>
> *It is desirable, therefore, that much of the traditionary arithmetic of the schools should be replaced by new material which will provide a wider mathematical training for the child, and that there should be included in the mathematical training of all normal children suitable parts of mensuration, algebra, geometry, and trigonometry, especially such as are necessary for the intelligent comprehension of some of the problems of our everyday life.*

It will, of course, not be forgotten that the Consultative Committee, in their Report, envisaged the possible raising of the school-leaving age, with the consequent opportunity for the development of a full four-year course in Arithmetic and Elementary Mathematics. It is the author's purpose in this section of the PRACTICAL SENIOR TEACHER to indicate how far the above general principles may be incorporated in suitable syllabuses for the average boy or girl in the ordinary Senior School.

What may Safely be Discarded

In arriving at any conclusion as to what may safely be jettisoned from the traditional arithmetical syllabus, teachers appear to be generally agreed upon a number of unnecessary topics which have hitherto been included. The Hadow Report itself suggests that the following may profitably be discarded—

Complicated fractions.

Recurring Decimals.

Complicated examples in H.C.F. and L.C.M.

Cube-root.

The later *Handbook of Suggestions for Teachers* (1927 edition) indicates in more detail how the purely arithmetical side of the syllabus may be lightened—

> (*a*) Sums connected with buying and selling must necessarily form a considerable portion of any course in arithmetic, but a good many commercial applications, which formerly were often regarded as separate "rules," may well be omitted. It is unnecessary in the ordinary school, for example, to deal with "Stocks and Shares," "Foreign Exchange," "Partnerships," "True Discount," and "Compound Interest," except in the simplest form, though these topics would be quite appropriate in Advanced Classes with a commercial bias.
>
> (*b*) Many textbooks on arithmetic devote special sections to particular types of problems concerned with partnerships, time and work, pipes filling cisterns, races and games of skill, clocks, mixtures, and the like. Some of these are of academic interest only, and none of them involves any new principles. As a rule it will be best, if they are taken at all, to treat them simply as problems, and not to teach any special methods of solving particular types. In many instances they are best worked by algebraical or graphical methods, and to show children how to solve them by arithmetic savours somewhat of the teaching of clever tricks.

With the omission of the above and similar topics, space will be found for the development of the more mathematical sides of the subject, such as mensuration, geometry, algebra, and graphs.

Accordingly, the "Hadow" Report at once proceeds, with some courage, to indicate this larger and more mathematical syllabus as follows—

The "Hadow" Suggested Syllabus

Numbers—Growth of the Number System.

Elementary operations with numbers.

Our money system with the usual applications. The meaning of a fraction. Simple operations with fractions. Decimals.

The measurement of length, area, volume, weight, capacity, and time, with appropriate tables.

The metric system.

Areas of rectangles, squares, triangles, surfaces of prisms, etc. Appropriate geometrical work.

Volumes of prisms.

Generalization of results in above work on areas, etc. Introduction of symbols. Construction of elementary formulae. Use and manipulation of formulae. Easy equations. Transformation of formulae for purposes of computation. Easy factors.

Use of squared paper. Construction, meaning, and use of graphs. Drawing to scale.

Meaning and use of Averages.

Factors; common factors; H.C.F. and L.C.M.

Simple algebraic examples.

Further work on fractions.

Decimalization of money. Calculation of Cost.

Ratio; constant ratios. Ratios connected with angles. Sine, cosine, and tangent of an angle. The right-angled triangle.

Surveying problems and other practical applications.

Square root.

Equal ratios; proportion; proportional quantities; proportional division. Similar figures.

Mensuration of the circle, cylinder, pyramid, cone and sphere, with appropriate geometry.

Percentages with applications to interest, insurances, etc. Compound interest.

Indices, logarithms.

Investments. Foreign currencies and methods of Exchange.

True discount and present worth.

The topics included in the above list make a very formidable array, and will possibly be regarded by many experienced teachers as much too ambitious to be covered by the ordinary pupil in the three years now available in the average Senior School.

Accordingly the Report is careful to explain the above syllabus as follows—

> This syllabus is intended to indicate a course of mathematics which may be considered suitable for a *four-year* course in a non-selective modern school for boys in an urban area, though modifications would often be made necessary by local conditions and special difficulties. Whether or not it is advisable in any given school to adopt the whole of the course or to add to it, depends upon the time available, the special circumstances of the school, and the bias which any particular teacher may give to the subject. In most girls' schools the course would probably need to be shortened owing to the fact that there is less time available for the subject. In rural schools there would also be omissions, and it would be adapted to the requirements of their special conditions by modifications in the treatment and changes in the emphasis on different parts of the curriculum.

We shall now proceed to discuss in detail the modern methods of approach to all the above topics, and in this connection we would urge every reader to study most carefully the following—

1. The "Hadow" Report (Board of Education). (The Education of the Adolescent.) Pages 214–220. Suggestions on Teaching. Elementary Mathematics.
2. *Handbook of Suggestions for Teachers.* (Board of Education.) Chap. V, pages 169–216 (1927 Edition). Arithmetic and Elementary Mathematics.
3. Any good textbooks on the Teaching of Arithmetic and Elementary Mathematics, e.g. *The Teaching of Arithmetic,* F. F. Potter (Sir Isaac Pitman & Sons, Ltd.).

In developing each topic we shall assume that the pupil, on entry to the Senior School or Department, has received a good grounding in the Junior School in all the fundamental operations in number, money, weights and measures, and the simplest fractions and decimals; and has also made some acquaintance with the idea of area and volume (rectangular), and their measurement. In brief, we shall assume that the normal pupil, on entry, has reached the standard of the ordinary qualifying examination required for the usual Special Place or Scholarship examination at about the age of 11, though we shall be mindful of the fact that every non-selective Senior School must contain a good proportion of "C" pupils who will not have reached this standard, and for whom a special simplified course must be devised.

Co-ordination with the Junior School

The importance of definite co-ordination with the Junior School cannot be over-emphasized. This co-operation is not a difficult matter where the pupils enter the Senior School mainly from a single Junior Department, but is much more difficult where the Senior School receives its entrants from a number of Junior Schools. Here, conference and agreement between the staffs is essential, if the transition from Junior to Senior School is to be made easily and without loss of efficiency.

The staffs of the schools in such a group should agree not only upon the content of the work to be done in the Junior Schools but also upon the methods to be employed, particularly in such vexed questions as subtraction and decimal manipulations. It is a sad waste of time and of energy for both teachers and pupils if children are obliged to learn new methods on entering the Senior School. The *Handbook of Suggestions* (Board of Education) is specific upon this point—

> The practice sometimes adopted of drawing up for the Junior Stage of all schools an agreed minimum syllabus which is also accepted as the examination syllabus for admission to Central and Secondary Schools, is therefore to be commended. Such a syllabus need not prevent individual teachers from extending the scope of the instruction in the case of the more capable pupils, but it should counteract any tendency to attempt too ambitious a course at the expense of thoroughness. It will probably be agreed that a minimum course for this stage should at least include a thorough groundwork in notation; a knowledge of the first four rules applied to money, and the ordinary English measures of length, area, capacity, weight, and time; an elementary acquaintance with vulgar and decimal fractions, together with simple notions of geometrical form and some skill in practical measurement.
>
> Whether such a plan is followed or not it is necessary that co-operation between the respective head teachers should exist wherever children are transferred from one school to another. This applies equally to the transference from Infants' to Junior School, and from Junior to Senior or Central or Secondary School, and from the Elementary to the Technical School. Complete co-ordination of syllabuses may seldom be feasible, but at all events much may be done to avoid waste of effort on the part of the teacher and marking time on the part of the child. It is desirable also that in the schools of any area where interchange of pupils takes place, there shall be general agreement on the more important points of method, e.g. whether multiplication shall start with the digit of highest or lowest value in the multiplier.

Mental Work

The subject known as mental arithmetic will have occupied a prominent place in the work of the Junior School, but is not less important in the Senior School. While it is obvious that all work in arithmetic and mathematics is really "mental," it is customary to restrict the term mental arithmetic to those calculations which are accomplished without the aid of writing materials. It follows that most of the examples thus worked "in the head" will be based upon simple numbers, or will consist of conventional short cuts. It is also clear that, apart from these conventional tricks, easily memorized and applied (e.g. cost of dozens and scores), mental arithmetic differs only from written arithmetic in the size of the numbers, and the number of the operations employed. In the Senior

School, mental arithmetic will serve many purposes—

1. It will be constantly employed for revision of previous work. Short examples may be dictated or "graphed" and worked individually by the pupils, "answers only" being written down. This method has such obvious advantages over the traditional "oral" "hands-up" method, that it is not surprising to read in the *Handbook of Suggestions* that "This practice of writing down answers might well become universal."

2. Mental arithmetic is very generally employed in teaching new "rules" and topics, while new problems may frequently be elucidated for the pupils, if simple numbers are substituted and the problem thus cast into "mental" form.

3. Mental arithmetic may be treated solely as a collection of short cuts and special devices, but this aspect, though "useful" in the narrower sense, should not be permitted to obscure other equally valuable and useful aspects of mental arithmetic.

4. Finally, mental arithmetic may be regularly employed to develop those essential qualities of speed and accuracy which are so desirable in every educated person. For this purpose a large number of short "mental" examples may be periodically set, instead of the smaller number of longer problems, but it must be borne in mind that the qualities of concentration and persistent application required in solving the longer problems are perhaps equally as valuable as the qualities of speed and accuracy called for in the case of the shorter "mental" or "intelligence" questions, a point which is sometimes overlooked by the supporters of the "Speed and Accuracy" type of exercises.

Though less applicable to the other branches of mathematics, these methods of mental arithmetic are adaptable to the teaching of algebra and geometry, and few teachers to-day would attempt to dispense with oral introductions to new topics in dealing with these subjects.

ARITHMETIC

THE SIMPLE RULES

PROFICIENCY in the so-called Simple Rules is the basis of all the arithmetical and mathematical work in the Senior School. The requirements of later life demand that the pupil shall be able to perform these ordinary processes with accuracy, speed, and precision. Public opinion, which insistently voices this demand, is probably correct in this instance, though frequently those critics of the teacher who are most vocal and hostile in this matter are influenced only by the somewhat narrow outlook of the "business" world and the counting-house. The allegation is recurrent to-day that pupils, on leaving the "Elementary" School, are far less accurate in calculation than they were a generation or two ago, and that, by a simple inference, it must be that arithmetic is not taught to-day with the same precision, earnestness, and enthusiasm that marked the teacher's efforts in other and earlier days. To such criticism it may fairly be answered that the facts, as revealed by impartial investigations, do not warrant the allegations; that accuracy is as common to-day as it was formerly; that this accuracy covers a far wider field of mathematical training than was ever attempted in working through the older, narrowly restricted syllabuses; that such mechanical accuracy as was then sometimes achieved was only attained by laborious practice in this very limited field; that the accuracy of an automaton is not of necessity a sign of real intellect; and that pupils to-day can readily apply such mathematical knowledge as they possess to a much wider field of applications, problems, and projects, whereas the older type was proficient mainly in mechanical arithmetic, breaking down usually when faced with problems.

The sane view of this controversy as to accuracy yesterday and to-day is well expressed in the *Handbook of Suggestions*—

> In the reaction against a dogmatic treatment of "rules" and an undue insistence on neat and mechanical cyphering, accuracy in arithmetic is sometimes insufficiently regarded. Whatever results may be achieved in the direction of guiding intelligence, the teaching is not really successful unless the older children are able to work examples with precision and reasonable speed. By the age of 11 years or thereabouts accuracy in simple operations should be in great measure automatic. It depends first on a ready knowledge of the tables, and secondly upon concentration; but in the case of written work is greatly assisted by neatness of figuring and clear statement.
>
> Two suggestions with regard to the attainment of accuracy may be made—
>
> (*a*) Children should be required to review and check the working of each sum they may work; and when possible, they should compare each answer with an approximate answer previously obtained verbally.
>
> (*b*) Children should frequently be set to work quickly sums which present no difficulty as to method; in this way they may be led to combine speed with accuracy, and a valuable opportunity is afforded for revision. The amount of time spent in this practice will vary from school to school, but it should seldom amount to less than one lesson per week.

Addition

Pupils on entering the Senior School should be able to perform simple addition with accuracy and speed. Of all the fundamental operations, this is perhaps the one which is most constantly required in later life. Practice in addition must accordingly be continued regularly throughout the Senior School course. As indicated above, what is required is accurate, speedy, and almost automatic addition, together with adequate checking of totals. Every possible device should be employed; thus, where totals have been found in the ordinary way by adding *up*, the answers should be checked by adding *down*, i.e. working first by beginning with the *lowest* digit of the column, and checking by beginning with the *topmost* digit of the column. This simple device is a most valuable check. Similarly, in the addition of numbers arranged horizontally, addition of numbers from left to right should be checked by addition from right to left. The now familiar device of "Add rows and columns, and check by finding the grand total" is an admirable one, providing in its form the most adequate check and counter check.

Akin to this useful type of example is the interesting topic of magic squares, which, in the

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hands of a skilful teacher, may be made to yield numerous interesting exercises in the simple rules, such as the formation of new magic squares from given squares, and the completion of magic squares in which certain elements have been omitted.

Subtraction

This process should have been mastered in the Junior School, and it is sincerely hoped that all Junior pupils will have been taught by the method known as "equal additions." On this point, the *Handbook of Suggestions* is somewhat non-committal—

> There are several methods of teaching subtraction, and opinions differ as to their relative merits. It may be said, however, that although the method of "decomposition" permits of practical illustration, the old method of "borrowing and paying back," perhaps more logically described as the method of "equal additions," is considered by many teachers to produce a greater degree of accuracy.

But there is a further reason for advocating "equal additions," viz. that in later life, subtraction, for most people who have to use the process regularly, ceases to be simple subtraction and becomes, rather, what is aptly described as "complementary addition." The transition may be explained by an example—

The simplest subtraction sum, e.g. "From 100 take 73" may be viewed as a problem in addition, e.g. "What must be *added* to 73 to make 100?" This is then "worked" as follows—

3 **and 7** are 10.
Put down 7 and carry 1, as in addition.
1 and 7 are 8, **and 2** are 10. Put down 2.
Answer 27.

100
—
73
—
27
—

Here subtraction, though actually performed, appears in the simpler guise of addition. This process of subtraction performed by complementary addition is particularly valuable in examples such as the following—

Mechanical	*Problem*
Find the missing line in the following addition sum—	How many eggs are left out of 1,500, after selling 240, 360, 192, and 540?
xxxx 1,768 2,239 3,456 10,000	

In neither case is it necessary to find the answer by two operations, i.e. an addition followed by a subtraction. Taking the mechanical example, this may be readily worked in one operation as follows—

6, 15, 23 **and 7** are 30.
Put down 7 and carry 3.
3, 8, 11, 17 **and 3** are 20.
Put down 3 and carry 2.
2, 6, 8, 15 **and 5** are 20.
Put down 5 and carry 2.
2, 5, 7, 8 **and 2** are 10.
Put down 2.
Answer 2,537.

It will be noted that by this method it is not necessary to find first the total of the three given lines. It is for this reason that examples of this kind given in the various books of the writer's *Common-Sense Arithmetic* have been termed "Addition and Subtraction in one operation." It will be further noted that examples worked in this way are readily checked, for, as soon as the missing line has been found, its accuracy may at once be tested by a further addition of *all* the numbers.

Multiplication

Proficiency in multiplication is essential in arithmetic, and pupils are capable, with adequate practice, of reaching remarkable proficiency in the subject, since it depends very largely upon an automatic knowledge of "tables." Tables, of course, should have been acquired in the Junior School, but these will need careful revision with older pupils, especially "C" pupils. In actual practice most of the mistakes in multiplication arise from one of the following—

(*a*) Mistakes in the application of tables.

(*b*) Mistakes in allowing for the effect of o's in the multiplier.

(*c*) Inaccurate addition of partial products.

Actual methods of "setting out" and "working" a multiplication sum have varied in the course of time, as any *History of Arithmetic* will show, and to-day the traditional method of the nineteenth century, where the multiplication began with the right-hand digit of the multiplier, shows definite signs of being displaced by the more modern method of beginning with the *left-hand* digit, as advocated in the *Handbook of Suggestions*—

> In multiplication of numbers of more than two digits, the process should begin with the left-hand digit of the multiplier, as this method gives the most important figures first, and is specially useful in multiplication of decimals.

We illustrate the two alternatives by an example.

```
 Traditional        Modern
      679             679
      345             345
      ———             ———
     3395          2037
    2716            2716
   2037              3395
   ——————          ——————
   234255          234255
   ══════          ══════
```

The checking of a product, when found, may be performed in several ways—

1. By reworking the sum carefully in the way it was originally worked.
2. By interchanging multiplier and multiplicand, and working a new multiplication sum.
3. By dividing the product obtained, taking either the multiplicand or multiplier for divisor. The sum should work out exactly and give the original multiplier (or multiplicand) as the quotient.
4. By the process known as "casting out the nines."

The last process, formerly very popular with teachers, is now less often employed, as it is difficult to explain and has certain serious defects.

Division

Division is perhaps the most difficult of all the fundamental processes. Certainly, *Long* Division has proved a vale of tears and bitterness to successive generations of school children. Every experienced teacher has evolved certain devices for lightening the labour of teacher and taught, but still the process remains a toil and trial to all. Few hints can be given for simplifying the process. It is possible that teachers attempt to teach Long Division too soon, and accordingly teachers in the Senior School should not expect too great a proficiency in this process from pupils on their entry from the Junior School. On the other hand, a later approach does not relieve the teacher of Senior pupils from the task of teaching this subject thoroughly.

In the practice of Division sums with Senior pupils, due attention must be paid to the double aspect of division—

> A sum in division has two possible interpretations. The process of cyphering when 39 is divided by 3 is the same whether 39 things are to be divided into three equal groups or whether the question is how often a group of 3 things is contained in 39 things. In the first case the divisor is an abstract and the quotient a concrete number, in the second the divisor is concrete and the quotient abstract. The first process is sometimes spoken of as one of "sharing," the second as one of "measuring." (*Suggestions.*)

Finally, two excellent pieces of advice may be called from the same *Suggestions*—

> (*a*) In Long Division there is an advantage in placing the quotient *over* the dividend.
>
> (*b*) When a remainder is required (i.e. in Division) the answer should be expressed either as "rem. *x* units" or as "and *x* units over." The use of a + sign in this connection should be entirely prohibited.

Factors

In connection with the simple rules, particularly Multiplication and Division, the subject of factors and divisibility generally should receive constant attention—

> Rapid practice in resolving numbers within the limits of the multiplication table into pairs of factors provides an effective method of revising tables, and splitting numbers into prime factors is a simple extension of this useful practice. The applications of the latter exercise are so numerous and useful, e.g. in "common measures," "common multiples," and "cancelling," that it deserves more attention than it usually receives in Elementary Schools. No very great practice is needed to make children proficient in resolving small numbers at sight into their prime factors.
>
> At this stage, or later as opportunity offers, the simpler tests of divisibility should be taught. For rapidity of work in "reducing to lowest terms," and in "cancelling," children will appreciate the advantage of knowing the tests of divisibility by 10, 5, 2, 4, 8, and the simple rules can be made intelligible to them. The tests of divisibility by 3 and 9 should be taught, but the explanation of these rules is too difficult for most children in the Elementary School. (*Suggestions.*)

Multiplication and Division by Factors

Much attention was formerly devoted to the use of factors in multiplication and division, both of number and money, especially division with remainder, and the teaching of the method of calculating such remainders was highly popular both with teachers and examiners. Less attention is now given to such exercises, though at the elementary stage, where multipliers and divisors can be resolved into two or three simple factors, the method of factors is useful and appropriate. It is, however, fair to state that the average person, after school life has ended, seldom troubles either to multiply or to divide by factors, if any other method is available. The processes, therefore, need occupy but little space in a Senior School course, the ordinary methods of multiplication and division, when properly mastered, being just as speedy and just as intelligible to the average pupil.

Other Applications of Factors

Several applications of factors are mentioned in the extracts from the *Suggestions* given above, such as their use in finding Common Factors, H.C.F., Common Multiples, L.C.M., cancelling and reducing to lowest terms. A further useful application is their use in the extraction of square roots, especially of numbers which are perfect squares. Thus the number 7,056 is readily factorized as $2 \times 2 \times 2 \times 2 \times 3 \times 3 \times 7 \times 7$ or $2^4 \times 3^2 \times 7^2$, whence, by inspection, the square root of 7,056 is $2^2 \times 3 \times 7$, or 84. The finding of square roots by factors should precede the teaching of the general method.

Short Methods in Connection with the Simple Rules

Pupils should be encouraged to apply short methods to calculations of every kind, where possible. Multiplication and Division particularly lend themselves to these short methods. Thus in multiplication pupils should be aware of short methods for multipliers such as 99, 999, etc., and 25, 125, 250, and others. Again, they should be aware that multipliers such as 369 can be dealt with in two partial products and not three (since $36 = 9 \times 4$). Thus the example 485×369 may be worked as shown—

$$\begin{array}{rl} 458 & \\ 369 & \\ \hline 4{,}122\ldots & (a) \\ 164{,}88\ldots\ldots & (a) \times 4 \\ \hline 169{,}002 & \\ \hline\hline \end{array}$$

Later, pupils may be taught to bring simple algebraic identities to their aid in multiplication, such as $(a \pm b)^2 = a^2 \pm 2ab + b^2$ and $a^2 - b^2 = (a + b)(a - b)$.

Number Theory

It is fashionable to decry any attempt to investigate the Theory of Number in an Elementary School, even in a Senior School. Regard, it is stated, should be paid only to accuracy in the fundamental processes, to intelligence in their application, and to speed in both calculation and intelligence. But an enthusiastic teacher will find numerous opportunities in the course of his work for calling attention to what has well been described as the "eeriness" of number, by means of simple problems and quests. Space does not permit us to enlarge at any length on these possibilities, but it is fair to state that, just as "crossword" puzzles have a certain educational aspect, so number puzzles are worthy of a place in schools, at least for some of the brighter pupils.

ENGLISH MONEY

Examples involving the English money system must inevitably occupy a prominent place in every Senior School syllabus. It is perhaps true to state that in the past the mathematics of the older pupils has consisted of far too many "money sums," to the exclusion of other equally important and equally interesting topics. We have indicated, earlier in this section, how certain of these more academic money topics may be discarded, without loss, from the average syllabus, even if they should appear later in the course for those students intent upon a more specialized commercial course. But money plays such an important part in the life of every person that we must continue to devote considerable attention to "money sums," although the labour involved may lead us to regret, perhaps, that in this country the work of the teacher and pupil is made so much the heavier by the fact that our coinage is not on a decimal basis.

What Entrants to the Senior Schools Should Know

The pupil, on entry, ought to be thoroughly familiar, from his Junior Course in arithmetic, with the units of English money—the farthing, halfpenny, penny, shilling, and pound, and their connection with each other. He should also be able to add, subtract, multiply, and divide any sum of money within reasonable limits. The work of the Senior School will continue and extend this Junior School knowledge, and will add to the methods and applications of English money as the occasion arises.

Addition of Money

This process must receive regular attention. It is as fundamentally important as the addition of number, mentioned earlier. Public opinion demands that accuracy in the addition of money shall be taught, and public opinion in this connection is probably right. Certain alternative methods of adding farthings, or pence, or shillings are in vogue with different teachers, and space does not permit us to discuss their comparative merits, but the general principles of rapid calculation, followed by independent and reliable methods of *checking*, are as essential here as in other basic calculations. As in the case of number addition, so in money addition we may apply all the usual devices: vertical and horizontal additions; adding "rows and columns"; and "up and down" additions for checking; and others too numerous to mention. Here, too, the so-called mechanical sum may be regularly employed and the old device of "tots," not so long ago condemned as old-fashioned, may profitably be rehabilitated—at least, until such time as all addition of money has been "mechanized," and machines and "robots" relieve us of the tedious and chastening necessity of adding up columns of figures and sums of money.

Subtraction of Money

As in the case of Subtraction of Number, so in Subtraction of Money it is hoped that the Method of Equal Additions, or Complementary Addition, will be generally taught. Attention is sometimes drawn to the mechanically accurate manner in which a shopkeeper "makes up" the change, by counting out the balance. It might be objected that by this method the actual total charge is not of necessity apparent. An example makes this point clear. The shopkeeper, giving "change" out of 10s. for a purchase of 6s. 7½d., proceeds usually as follows: "And a halfpenny is 6s. 8d., and 4d. is 7s., and 3s. is 10s.," but it is not clear that he realizes that the actual change is 3s. 4½d., and in any case the method is more difficult to apply in any general subtraction, e.g. "What will make £1 13s. 6½d. up to £3 5s. 2d.?" Here it is better to proceed by the method of equal additions.

This method of complementary addition is easily extended in money sums to the type of example which has been termed "Addition and Subtraction in One Operation."

EXAMPLE—

Find the missing line in the following addition sum—

£	*s.*	*d.*
xx	*x*	*x*
17	16	7
24	18	9
37	12	10
£100	–	–

This is readily worked as follows—

10d., 1s. 7d., 2s. 2d. **and 10d.** makes 3s.
Put down 10d.; carry 3s.
3s., 15s., 33s., 49s. **and 11s.** make 60s. or £3.
Put down 11s.; carry £3.
3, 10, 14, 21 **and 9** make 30.
Put down 9; carry 3.
3, 6, 8, 9 **and 1** make 10.
Put down 1.

The missing line clearly is £19 11s. 10d., which is readily checked by a subsequent addition. The method is particularly useful in finding balances in accounts of every kind.

Multiplication

Many methods for the multiplication of English money are in vogue, each of which has its advocates among teachers. Possibly too much attention in the past has been devoted to the multiplication of money in the early stages, but Senior School pupils should be encouraged to employ various methods, including the method of Practice, which will be fully discussed later. Many of these methods are highly ingenious and interesting, and the whole subject forms a characteristic feature of English Arithmetic. Pupils must, of course, be able to multiply a sum of money by any reasonable multiplier, though the more elementary and cumbersome methods should be gradually replaced by such methods as Practice and methods based upon the decimalization of money.

Division of Money

Division of money, especially Long Division of money, will require considerable attention in the Senior Course. The method must be carefully taught, but, generally, pupils find it difficult and, on the whole, uninteresting. Short division, including factor division, on the other hand, presents fewer difficulties, unless in the latter case the exact remainder is required.

The double aspect of division—i.e. the "measuring" and "sharing" aspects, already mentioned in the case of division of number, become of great importance in dealing with money (as with any of our weights and measures), for clearly we can divide £12 17s. 6d. either by 30 ("sharing") or by 30 pence ("measuring"). The latter type of example is commonly known as Concrete Division, to distinguish it from Ordinary Division. The common type of example is worded somewhat as follows—

"How many people can have a guinea each out of £100, and how much is left?"

At the first stage, Concrete Division is usually performed by preliminary reduction of each of the quantities to the same unit. This process indeed is a most important application of the process of reduction, and since some change of units, i.e. from farthings through pence and shillings to pounds, is involved in practically all money calculations, we shall now discuss in some detail this subject of Reduction.

Reduction

Reduction, as a special type of example, is an unfortunate result of our illogical English system of Money, Weights, and Measures, with their units so arbitrarily connected.

In all money calculations it is necessary to proceed from one unit to the next with ease and speed. To do this, it is essential that constant and ample *oral* practice is given to the pupils. It was formerly fashionable to memorize the 'pence' table; but to-day mechanical work of this kind is less often insisted upon. On the other hand, pupils should be able to 'reduce' any number of farthings up to 48, and any number of pence up to 100 or 144, with automatic ease, while the reduction of shillings to pounds is so simple that it seldom gives any difficulty.

It is customary to condemn the long reduction sums which formerly occupied so much time in the middle years of a child's school life, and it is true that the actual 'real life' value of such an example as, "Reduce 1,000,000 farthings to £ s. d.," is not clear. Yet, as a means of giving practice in concentration, accuracy, and the use of 'tables,' such examples, if used occasionally, are not without value.

In all Reduction examples children should be encouraged to arrive at the answer required by the shortest possible method. Thus, in calculating the cost of 329 articles at 3d. each, the first step should be division by 4 to give shillings, and not multiplication by 3 to give pence. In this connection, it is very truly remarked in the *Suggestions* that "children are generally much too ready to reduce all money sums to pence."

A glance at any modern arithmetic textbook or class-book, such as the *Common-Sense* series, will indicate the important part played by Reduction in money examples of every kind.

Bills and Accounts

It is customary to include Bills and Accounts of every kind in the mathematical syllabus for a Senior School, and, for some reason not quite clear, it is fashionable to attach more importance to these in girls' schools than in boys' schools. The practice, however, is without doubt a correct one, for all girls and boys should be able to interpret, calculate, and check an ordinary tradesman's account. All that is necessary is to arrange that the 'Bills' and other exercises of the same type are as varied as possible, introducing all the ordinary types of accounts which ordinary people are accustomed to receive and to send.

Too much attention at this Senior stage need not be devoted to the heading, receipting, and other accessories to Bills, to which teachers formerly gave much attention, though the importance of teaching the pupil how to receipt a bill must not be overlooked.

In Senior Schools for girls, Arithmetic of this more domestic kind should not be permitted to usurp the whole of the syllabus, and room in the syllabus should be found for some of the more mathematical topics, particularly in the last year or two of the course. But of the primary importance of money sums, especially 'shopping' sums, there is no doubt. The *Suggestions* are emphatic on this point—

> Since the main use which many children will make of arithmetic after leaving school will be in doing quite ordinary shopping sums, frequent practice in these is essential. It is far from unusual to find children, who can decimalize money easily, or who can work quickly and accurately, according to rule, such sums as "two dozen articles at 1s. 11¾d. each," failing to give correctly the price of 2½ yd. of material at 1s. 10d. a yard, or the change to be expected out of 10s. when 5s. 4½d. is spent.

The Arithmetic of Citizenship

Space must be found, both in boys' schools and in girls' schools, for a sound treatment of the arithmetical aspects of life as a householder and as a citizen, both as ratepayer and as taxpayer—

> Careful attention should be paid especially in the upper part of the school to types of sums which have some bearing on the children's after-school life. Calculations will be specially valuable if based upon data supplied by the children which incorporate current prices of commodities and those methods of paying wages prevalent in the surrounding district. Many teachers will doubtless have friends closely associated with the industries of the school neighbourhood from whom they will be able to obtain information as to prices, costs, rates of pay, and the types of calculation generally employed, while market reports and advertisements in the local newspapers may also furnish much useful material of the same kind. Regard should also be had to true economy and the examples chosen should illustrate such facts as the dearness of buying in small quantities, the false saving sometimes associated with cheapness, and the utility of insurance of various kinds. Exercises might be given on local rates, proportion of rent which is paid in lieu of rates, and on the payments which have to be made by employers and employed in respect of Pensions and of Health and Unemployment Insurance. (*Suggestions.*)

Savings and Investments

We have indicated in the opening paragraphs of this section that Stocks and Shares, as taught in the old academic way, may well be omitted, but this is not to be construed to mean that our syllabuses should contain no reference to the subject of Thrift and Savings. This topic leads naturally to the discussion of the subject of Interest and its teaching, and accordingly we shall deal at considerable length with the matter in the later chapter on Interest.

Short Methods

English money sums lend themselves readily to short methods and short cuts of every kind. Many of these methods depend upon arbitrary relations between units, but they are so useful that they should be regularly taught and practised. Among these we may mention such connections as units and dozens with pence and shillings, and units and scores with shillings and pounds. A modern textbook or classbook of arithmetic, such as *Common-Sense Arithmetic for Senior Boys* and the corresponding series for Girls (Pitman), contains ample graded practice in Short Methods of every kind.

Further and more detailed discussion of all the above topics will be found in Chapters IV and V of *The Teaching of Arithmetic* (Pitman).

Finally, those who would condemn our very arbitrary system of money units might well turn to the history of these units, and discover for themselves much interesting lore. They may learn, for instance, why *£* represents pounds and *d.* pence; whether there is any connection between the pound in money and the pound in weight; what coins formerly in use have now disappeared; and other information which will frequently lighten the classroom round of money sums.

WEIGHTS AND MEASURES

Weights and Measures will have figured largely in the syllabuses for the last year in every good Junior School. By means of concrete methods, by actual handling of weights and measures, by "shopping," by calculations and problems, the Junior pupils will have become familiar with the simpler units, and it is the work of the Senior School to see that such knowledge does not fade through lack of use, but that the subject is regularly revised and extended in each of the Senior years. This is particularly necessary at the present period, when so many of the "reorganized" schools are in the first flush of fine enthusiasm, and are in danger of attempting a syllabus in mathematics too difficult for the average pupil, and more suitable to an ordinary Secondary School.

In spite of all the idiosyncrasies of the English "Tables," and the arbitrary nature and connection of the units in common use, the work involved in teaching Weights and Measures is not of very great difficulty if one or two precautions are observed, e.g.—

1. All obsolete units and measures should be omitted.

2. Units actually in common use should be made familiar to the pupils, through practical work, as *realities* and not merely as words in a Table.

3. The units, e.g. lb., yd., hour, etc., should be constantly associated with money in the form of costs.

With these and other aids, teachers may confidently attack the "Compound Rules," for the new mathematical knowledge required to deal with these is not in itself very great. In this attack upon Compound Rules and Tables, Reduction is obviously involved, and its place in the syllabus must accordingly be discussed.

Reduction

This process formerly occupied a very serious and important place in the arithmetical syllabus of the middle school. Gradually, however, it has been realized by teachers and textbook writers that lengthy reductions have no intrinsic educational merit and very few practical applications.

> Reduction is an unfortunate consequence of our mixed system of units, and too much stress has often been laid upon it. If the common tables of weights and measures have been intelligently taught, simple steps in reduction present no great difficulty, and it is seldom necessary to combine all the steps for such reductions as "tons to ounces" or "inches to miles." These reductions are not real; they necessarily involve large numbers and are principally useful as a test of accuracy. (*Suggestions.*)

But reduction, as we have noted, is involved in nearly every process comprised in the general term "Compound Rules," and, accordingly, cannot be entirely neglected. Long purposeless reductions will, of course, be avoided, but much may be done if use is made of some simple relations which exist between the common units. Among these we may mention the following—

1. A halfpenny is 1 in. in diameter.

2. 3 pennies or 5 halfpennies or 10 farthings weigh 1 oz.

3. A gallon of water weighs 10 lb.

These simple facts give an endless variety of examples, of which the following are typical—

1. What is the value of the halfpennies in a line 1 mile long?

2. How long a line could be made with £1 in halfpennies?

3. What is the value of 1 ton of pennies? (or halfpennies or farthings.)

4. What is the weight of £10 in pennies?

5. How long a line could you make with 14 lb. weight of halfpence?

6. What is the difference in weight between £1 in pence and £1 in halfpence?

7. What is the difference in value between 28 lb. in pence and 28 lb. in halfpence?

Examples of this kind give excellent practice in Reduction and never fail to interest pupils.

The principle may be extended to Time, with examples such as the following—

1. If a man earns 1d. per minute, what will he earn in a day of 8½ hours?

2. If the upkeep of a hospital is equal to 1d. per second, what is the cost per week?

Many more examples of this type will be found in the writer's series of *Common-Sense Arithmetics for Senior Boys* and *for Senior Girls.*

Length

The Table of Length must be made thoroughly familiar to the pupils; particularly the more common units and their relation to each other, e.g. inches, feet, and yards; yards and miles; miles and furlongs. Less importance is now attached to such units as the rod, pole, or perch, and the "chain," and more attention is given to miles, half-miles, quarter-miles, and yards. These units should have been well taught in the Junior School, and all that is necessary in the Senior Course is to keep alive the knowledge and the calculating ability there acquired, for it is disconcerting to a teacher to find pupils, sometimes at the top of the Senior School, who are familiar with fairly advanced mathematical topics and processes, and yet fail dismally when confronted with a simple problem involving ordinary weights and measures.

The units themselves are of great historical interest, and the pupils may be made aware, at this stage, of the history and derivation of certainly some of these units, if not all. The inch, the yard, the pole, the chain, the furlong, the mile, all have a fascinating history which will interest most pupils.

'Rules', including "Reduction" in Length, will not trouble pupils much at the Senior stage, if they are revised at regular intervals, and time may now be found for more interesting applications of Length. Among these are the data upon which all mensuration is based, map scales and scale drawing generally, but these topics fall naturally into the more geometrical part of the syllabus, and will accordingly be discussed later.

Problems in Length abound, but should be *real*. Contrast the following—

(*a*) *Mechanical*. Divide 1 furlong by 7 ft. 4 in.

(*b*) *Real*. How many times will a bicycle wheel, which is 88 in. round, turn in travelling 1 furlong?

The first (*a*) is dull and pointless, while (*b*) is real and interesting.

Distance and Time—Speed

There is one aspect of Length to which special attention must be directed in the Senior School, and that is the topic of Uniform Motion. The pupil must be thoroughly familiar with speeds, especially speeds in miles per hour. He must be able to calculate speeds in miles per hour from given data; he must be able to deduce the distance travelled in any given time at a given speed; he must be able to work simple problems involving speeds, and to draw simple graphs to illustrate velocity and motion. He should be familiar with modern speeds and records in connection with such means of locomotion as pedal cycles, motor-cycles, motor-cars, trains, and aeroplanes. He should also know that a "knot" is a speed, and not a unit of length, while in all cases he should be able to calculate average speed where necessary. This question of speed is considered by the writer to be of such importance in the modern world that special attention is devoted to it in the new series of *Common-Sense Arithmetics for Senior Schools*.

Weight

The Table of Weight must be thoroughly familiar to the pupils. The tendency in the last decade or two has been to simplify considerably this section of the syllabus, and pupils to-day are frequently not even troubled with the term *Avoirdupois*, while *Troy* Weight has been definitely excluded from schools for many years. The modern tendency is to concentrate upon the common units—the ton, the hundredweight, the quarter, the pound, and the ounce. These again should be familiar to the pupils from the Junior Stage, and will need only regular revision in the Senior School. The less common term "stone" (variously defined in different connections) may well be avoided, save in its common use in connection with the weights of people.

As in the Table of Length, so the units of Weight have a history of their own, and pupils should be made familiar with the evolution of these units, particularly the hundredweight. The work set will follow the usual course of Rules (including Reduction) and Applications. In the problems set, use should be made, as indicated above, of the connection of units of weight with other units, such as the relation of pounds and gallons and cubic feet of water, while constant practice should be given in examples combining weight and money. Thus pupils should be able to proceed readily from the cost per cwt. to the cost per ton, and *vice versa*.

Capacity

The Table of Capacity need not detain us very long, except to observe that it is really *two* tables, formerly described as 'Liquid' and 'Dry.' This is obvious when we think of a *gallon* of whisky and a *bushel* of corn. Obsolete measures, such as *pottles*, *firkins*, *puncheons*, and *pipes*, are by general consent omitted to-day from textbooks and syllabuses.

More important is the connection between the weight, capacity, and volume of the standard substance, water. Thus all Senior pupils should be thoroughly familiar with such connections as—

1 cub. ft. = 6¼ gallons.

and 1 gallon of water weighs 10 lb.

These are very convenient and simple relations from which numerous other relations may be deduced. Among these we may note the following—

1 cub. ft. of water weighs 62½ lb.

100 gallons = 16 cub. ft.

1 ton of water = 224 gallons.

From these it follows that 1 ton of water occupies 35·84 cub. ft. (or approx. 36 cub. ft.) of space.

Finally, through the universal fuel *petrol*, the gallon can be connected with distance and speed in that aspect of locomotion which is so important to the economical motorist—the number of miles per gallon.

Time and Its Measurement

In dealing with the subject of *Time* we are dealing with a measure which is not merely English but universal. In the past, the realities of the subject have been obscured by lengthy reductions of seconds to weeks, etc., but to-day we approach the subject less from its aspect of forming a convenient basis for 'sums,' and more from its importance as a primary necessity of civilized life.

Thus our Senior pupils must not only know the 'Table'—seconds, minutes, hours, days—but they must be familiar with other aspects and applications, such as the following—

Time and Distance—Speeds (discussed above).
Time-tables of every kind.
Summer-Time and Greenwich Time.
Clock Times and Longitude.
Time in connection with Months, and
Dates and the Calendar generally.

It may be objected that these topics are General Knowledge, or that they are geographical rather than mathematical. It is true that they afford less opportunity for 'sums' of the traditional kind, but it is equally true that the knowledge they comprise is essential to every educated person.

Railway and other time-tables, in particular, prove difficult to many pupils, and they should accordingly be exercised in using the time-tables *as actually printed*; in finding most suitable trains for a given purpose; in planning excursions; and in all the ordinary applications of time-tables to ordinary life.

Again, steamships and their arrivals and departures provide splendid practice in reckoning from one given date to another, while, generally, the pupil should be familiar with all the apparent idiosyncrasies of our present Calendar. Incidentally, it may be noted that the history of the evolution of this calendar, with its varying months, throws most interesting light upon these apparent inconsistencies.

Square Measure

This Measure need not detain us at this stage, as we shall return to it in the discussion of the teaching of Mensuration. It will be noted that this measure, as in Capacity, is capable of being regarded from two points of view, e.g. (*a*) the measurement of smaller areas of every kind, involving square inches, square feet, and square yards, and (*b*) the measurement of larger areas, usually land, involving acres, roods, poles, and occasionally square miles. In this connection, time should be found to demonstrate the historical connection between the furlong and the acre. It will, of course, be noted that a square furlong—(220 × 220) sq. yd.—contains exactly 10 acres.

Conclusion

With the above remarks on square measure we must leave this interesting topic of Weights and Measures, but we hope enough has been said to indicate the importance of continuing and extending the pupil's knowledge of, and practice in, Weights and Measures in the Senior School. Much of this practice will undoubtedly be interwoven with work in other subjects, such as Handwork, Woodwork, and Metalwork, Housewifery including Cooking, Gardening, and indeed practical pursuits of every kind, and not the least useful part of the training in the use of Weights and Measures will be the insistence of the teacher upon *accurate* measurements of every kind, impressing upon pupils the essential truth that the most faultless calculations are valueless, if based upon faulty data, which in turn results from faulty and inaccurate measurement.

In order to emphasize this point, the pupils should occasionally be given an 'all-practical' example, or a 'figureless' sum, in the form of a quest or project, where all the data must be accurately collected and checked, before any calculations can be performed.

PRACTICE AND ALIQUOT PARTS

Closely allied to Compound Multiplication of every kind is the process conveniently termed Practice. It has been the custom in recent years to condemn the long traditional practice sum, and certainly it is not necessary to ask our pupils to calculate the cost of 35,689 articles at £27 13s. 9¾d. each, or of 27 tons 17 cwt. 3 qr. 14 lb. 8 oz. at £38 10s. per ton. But Practice is a *method*—highly convenient, and of general application—rather than a special type of sum. This point is well emphasized in the *Suggestions*—

> Practice is a convenient and practical method of multiplication, originally brought into use to enable business calculations to be made with greater ease and rapidity. As a highly convenient method of multiplication, capable of application in all cases, it should not be restricted to finding costs with £1 as unit. It has the advantage of providing scholars with opportunities of devising short and easy cuts for themselves, and the selection of the unit and the grouping of the parts should in the first instance be left to them. The method may sometimes be usefully applied to the multiplication of vulgar and of decimal fractions; to the calculation of simple and compound interest; to finding a percentage of a given compound quantity; to problems involving rates, dividends, and so forth. It affords an easy method of constructing ready-reckoners, including discount and interest tables. The general application of the method to compound rules requires a knowledge of "aliquot parts" of all kinds of quantities, and scholars should have sufficient practice to enable them, with confidence and rapidity, to split any quantity into convenient aliquot parts and into "parts of parts."

This extract emphasizes the point already stated, viz. that Practice is a *method*, to be applied to calculations in many different subjects rather than a special type of 'costing' sum. The whole subject is fully discussed in Chapter XV of the writer's *Teaching of Arithmetic* (Pitman), and is there illustrated by calculations of many kinds. We shall refer again to instances where Practice may be usefully applied in dealing later with various topics, and in consequence we give only a few illustrative examples here.

1. *Traditional Type.*

Find the cost of 93 articles at £3 16s. 6d. each.

Take £1 as unit—

	£93			= cost at £1 each
	3			
	279			
10s. = ½	46	10	–	= cost at 10s. each
5s. = ½	23	5	–	= ,, ,, 5s. ,,
1s. = ⅕	4	13	–	= ,, ,, 1s. ,,
6d. = ½	2	6	6	= ,, ,, 6d. ,,
	355	14	6	= ,, ,, £3 16s. 6d. each

2. Find the cost of 57 books at 8½d. each. Take 1s. as unit.

	£	*s.*	*d.*	
57 at 1s. =	2	17	–	
6d. = ½	1	8	6	= cost at 6d. each
2d. = ⅓		9	6	= ,, ,, 2d. ,,
½d. = ¼		2	4½	= ,, ,, ½d. ,,
	£2	–	4½	

Alternatively, take 1d. as unit.

	£	*s.*	*d.*	
57 at 1d. =		4	9	
57 at 8d. =	1	18	–	= cost at 8d. each.
57 at ½d. =		2	4½	= ,, ½d. ,,
	£2	–	4½	

3. Find the rates payable on £57 10s. at 9s. 8d. in the £.

Take £1 as unit.

	£	s.	d.
Rates payable at £1 =	57	10	–
5s. = $\frac{1}{4}$	14	7	6
4s. = $\frac{1}{5}$	11	10	–
8d. = $\frac{1}{6}$	1	18	4
	£27	15	10

Alternatively, take 1s. as unit.

	£	s.	d.	
Rates payable at 1s. =	2	17	6	
,, ,, 10s. =	28	15	–	
4d. =		19	2	
By subtraction	£27	15	10	Answer

Similar methods may be applied to most cases of Rates, Taxes, Dividends, Commissions, Duty, Bankruptcy Dividends and, indeed, all problems involving payments in the £.

4. Find the cost of $9\frac{3}{4}$ yd. at 7s. 11d. per yd.

	£	s.	d.	
		7	11	= cost of 1 yd.
			9	
	3	11	3	= ,, ,, 9 ,,
$\frac{1}{2}$ yd.		3	$11\frac{1}{2}$	= ,, ,, $\frac{1}{2}$,,
$\frac{1}{4}$ yd		1	$11\frac{3}{4}$	= ,, ,, $\frac{1}{4}$,,
	£3	17	$2\frac{1}{4}$	

Alternatively—

	£	s.	d.	
		7	11	
			10	
	£3	19	2	= cost of 10 yd.
		1	$11\frac{3}{4}$	= ,, ,, $\frac{1}{4}$,,
By subtraction	£3	17	$2\frac{1}{4}$	= ,, ,, $9\frac{3}{4}$,,

The application of the method to decimals, percentages, interest, etc., will be taken later. Compound Practice involves no new principles and need not detain us.

Finally, the mathematically-minded may care to note that "Practice" is merely the ingenious numerical application of the fundamental algebraical identity—

$$a(b \pm c \pm d \pm e \ .\ .\ .\ .) = ab \pm ac \pm ad \pm ae \ .\ .\ .$$

Thus, taking (*a*) above we have merely utilized the fact that—

£3 16*s*. 6*d*. × 93

is the same as—

(£3 × 93) + (10s. × 93) + (5s. × 93) + (1s. × 93) + (6d. × 93)

FRACTIONS

It is part of the work of the Senior School in mathematics to consolidate and amplify the knowledge of Fractions which the pupil has gained in the Junior School. This knowledge, in the best Junior Schools, may be very considerable. To quote from the *Suggestions*—

> Children may become acquainted with the simplest fractions at a very early stage. Fractions are approached in the Infants' School; children become familiar with the fractional notation in working sums in halfpence and farthings. By means of handwork involving measurement they can extend their use of the notation and can learn to see that a fraction such as $\frac{3}{5}$ is greater than $\frac{3}{8}$ without actual manipulation of figures; it can also be made apparent to them that $\frac{4}{8}$ is equal to $\frac{1}{2}$ without first learning a rule for the purpose later on; with the aid of squared paper or a ruler an easy addition sum such as $\frac{1}{2} + \frac{1}{5} = \frac{7}{10}$ can be illustrated. Similarly it is easy to devise exercises to show that $\frac{2}{3}$ of $\frac{7}{10} = \frac{7}{15}$ and so on.

Armed with real knowledge of this kind, our pupils should not fear formal fractions in the Senior School. On the other hand, the opinion has been prevalent for some considerable time that the work in fractions in the Senior School has been overdone.

> It is probable that the ordinary school treatment of vulgar fractions is too elaborate; too much time may easily be spent in their manipulation, and more particularly in the simplification of long complex fractions. Also, where fractions with large denominations are avoided, there remains no reason for setting the difficult questions in L.C.M. and H.C.F. to which undue attention is often paid. Questions in L.C.M. and H.C.F. which cannot be solved by the inspection of factors may well be deferred or entirely omitted. (*Suggestions*.)

The criticism is justified when one remembers the extraordinarily difficult and complex examples which were practised only a decade or two ago, and still linger in some schools, but, with the above warning clearly before us, it is necessary to determine, for the purposes of our syllabus, exactly what knowledge of fractions we desire boys or girls in a Senior School to possess. We may summarize this as follows—

1. They should possess some knowledge of fractional theory—they should at least know, e.g. that $\frac{1}{4}$ is greater than $\frac{1}{5}$.
2. They should be able to proceed readily from "mixed numbers" to "improper" fractions and *vice versa*.
3. They should be able to reduce a fraction to its lowest terms.
4. They should be able to add, subtract, multiply, and divide simple fractions.
5. They should be able to express one quantity as the fraction of another and to evaluate a given fraction of a given quantity.
6. They should be able to apply fractional methods to appropriate problems.

Rules

The four Rules in fractions seldom present any difficulties to average pupils. The most difficult rule is perhaps Subtraction, and the easiest rules are Multiplication and Division. Too much time need not be devoted to the explanation or "proof" of a rule—it is enough at the ordinary Senior School stage if the pupil can apply the rule readily and accurately. Regular revision practice is, of course, necessary but, while the difficulty of the examples will be gradually extended, little time, if any, should be devoted to elaborate and complex simplifications.

Applications

1. Finding a Given Fraction of a Given Quantity.

This process is usually straightforward multiplication or division and really does not appear to the pupil as involving fractions directly.

Example.

Find $\frac{5}{6}$ of £2 12s. 6d.

	£	*s.*	*d.*
Clearly: $\frac{1}{6}$ by division =		8	9
whence $\frac{5}{6}$ =	2	3	9

The same result, on the alternative method of practice, could have been obtained by subtraction, e.g.—

	£	*s.*	*d.*
1 =	2	12	6
$\frac{1}{6}$ =		8	9
By subtraction $\frac{5}{6}$ =	2	3	9

The inverse type of this straightforward calculation should receive regular attention.

Example. $\frac{4}{5}$ of a sum of money is £2 2s. What is the sum of money?

Just as the direct type is really worked by fractional multiplication, so this inverse type is solved by fractional division, e.g. the answer required is given by—

£2 2s. ÷ $\frac{4}{5}$ or
£2 2s. × $\frac{5}{4}$ = £2 12s. 6d.

All such examples may, of course, be worked from first principles, but the pupils should recognize them at sight as examples of fractional division.

2. Expressing One Quantity as a Fraction of Another Quantity.

This is a straightforward calculation, usually dependent upon reduction. Care should be taken that convenient units are chosen. Thus, in the example—

"Express 12s. 3d. as the fraction of £1"

the pupil should note that it is *not* necessary to reduce each sum of money to pence, but that the calculation is readily performed through the unit 1s., i.e.—

First step $\frac{12\frac{1}{4}}{20}$

Second step $\frac{49}{80}$

Later, we shall note that this same method can readily be applied to the process of changing decimals to vulgar fractions, e.g. $\cdot 65 = \frac{6\frac{1}{2}}{10} = \frac{13}{20}$.

Multiplication and Division by Mixed Numbers

In the section on Practice we have indicated that an example such as "Multiply £3 10s. by $1\frac{7}{8}$ may readily be evaluated by practice methods and that it is not necessary always to proceed by "improper fractions" such as $\frac{15}{8}$.

Division by mixed numbers is of very definite assistance in such calculations as the following—

(*a*) $4\frac{3}{4}$ yd. cost £1 3s. 9d. What was the cost per yard?

(*b*) A train travelled 176 miles in 3 hours 40 minutes. What was its speed in miles per hour?

Example (*a*) is easily solved as

£1 3s. 9d. ÷ $4\frac{3}{4}$
or £1 3s. 9d. × $\frac{4}{19}$ = 5s.

while example (*b*) almost as readily becomes

176 ÷ $3\frac{2}{3}$
or 176 × $\frac{3}{11}$ = 48 m.p.h.

Pupils should be taught to recognize and apply this process of fractional division on every possible occasion.

Traditional Problems in Fractions

These are not numerous, but there is one particular type which deserves attention, and that is the "Remainder" type.

EXAMPLE. A man spends $\frac{3}{4}$ of his money at one shop and $\frac{3}{4}$ of the remainder at another shop. If he has 2s. 6d. left, how much had he at first?

If attention is concentrated on the remainder at each step, this type presents no difficulty. Taking the above example, we have

	Fraction Spent	*Fraction Remaining*
(*a*)	$\frac{3}{4}$	$\frac{1}{4}$
(*b*)	$\frac{3}{4} \times \frac{1}{4}$	$\frac{1}{4} \times \frac{1}{4}$ or $\frac{1}{16}$

Hence the original amount was 2s. 6d. × 16 or £2, which is readily checked. Such an example might be solved by analogy as follows—

Assume the man had £1 at first.
First amount spent = 15s.
First remainder = 5s.
Second amount spent = 3s. 9d.
Final remainder = 1s. 3d.

Clearly, if £1 leaves finally 1s. 3d., then 2s. 6d. must have been originally £2. On the whole, however, the direct method of solution is to be preferred.

Many other fractional types of examples may be made to depend upon fractions for solution. Among these are the well-known Work, Pipes, and Clock sums, but, in the words of the *Suggestions* already quoted, these "are of academic interest only and none of them involves any new principles. As a rule it will be best, if they are taken at all, to treat them simply as problems and not to teach any special methods of solving particular types. In many instances they are best worked by algebraical or graphical methods, and to show children how to solve them by arithmetic savours somewhat of the teaching of clever tricks."

In conclusion we would recommend teachers, in revising and extending the teaching of fractions, to have regard to all the warnings mentioned above. Thus the syllabus must not be too elaborate. In particular, the denominators employed should be reasonable; "rules" should not be practised blindly and mechanically; applications should be numerous and real; and traditional fractional problems should be avoided.

The primary object of the course should be to give the pupils a ready facility in the simple processes and in the applications of fractions to compound quantities of every kind, rather than to continue practice in fractions and fractional rules merely *as* fractions. In a word, common sense and not pedantry is peculiarly necessary in dealing with the subject of Vulgar Fractions in the ordinary Senior School.

DECIMALS

In the absence of a decimal coinage and of weights and measures on a decimal basis in England, the teaching of decimals in this country suffers from serious disadvantages. Traditionally, the subject of decimals has usually been postponed in schools until fractions have been exhaustively treated. The result has been that, to an Englishman, decimals usually are considered "difficult" and even foreign, for there is always an air of unreality in speaking of £3·65 or 2·7 yd. Further, the tendency in schools has been to change decimal fractions to vulgar fractions wherever possible, and so to miss completely the great advantage contained in simple decimal manipulations as compared with the comparatively clumsy methods employed in the evaluation of fractions.

It is accordingly, perhaps, the most important task of the Senior teacher to give to his pupils a thorough grounding in the manipulation and application of decimals.

Fortunately, decimals are not so much feared to-day, either by teachers or pupils, as they were formerly, for it is customary now to begin decimal manipulations in schools at a very early age. If justification is needed for this change of attitude, it is well expressed in the *Suggestions*—

> It is the traditional practice to study vulgar fractions before decimals. To a certain extent this plan is sound, for "halves" and "quarters" are easier than the easiest decimals, but, once the beginner can deal with these very elementary vulgar fractions, there is no reason why he should not proceed to decimals. There is, indeed, every reason why he should study decimals before occupying himself with vulgar fractions of a difficult kind. Vulgar fractions with large denominations are cumbersome and of limited utility, whilst decimals are comparatively easy to handle, and have many practical applications.

Assuming that this sane advice is generally acted upon in modern Junior Schools and classes, it follows that pupils, on entry to the Senior School, are not entirely "new" to decimals, but have some acquaintance with both their meaning, and manipulation, and their applications to quantities and problems. Thus, through inches and tenths of inches, they will have used the decimal notation; they will have added and subtracted simple decimals (to one or two decimal places), and they will have multiplied and divided decimal quantities, using whole number multipliers and divisors. The task of the Senior teacher is to extend and deepen this knowledge, both of processes and of applications, and to ensure that the pupil, on leaving the Senior School, does not fear or avoid decimals, but can interpret and manipulate them with ease, speed, and accuracy. On the other hand, the treatment of decimals in the Senior School should not be too elaborate—

> An elementary acquaintance with decimal fractions may be expected of all pupils before they leave school, but it may be advantageous in certain schools to restrict the work to sums involving not more than one or two places of decimals. The extent to which the teaching of decimals is carried will, of course, vary largely according to the circumstances of the school, but complicated manipulations of figures are out of place in any Elementary School, and very little stress need be laid upon recurring decimals. (*Suggestions*.)

With this advice in mind we may proceed at once to the treatment of decimals in the way we think they may profitably be explored in the Senior School.

Theory

Tenths, hundredths, and even thousandths are readily demonstrated as realities through exercises in length, area, and volume. All that is necessary is practical work with rulers, graduated in inches and tenths, squared paper ruled in inches and tenths (to show hundredths), and, if necessary, a cube to show thousandths. Very real illustrations of decimal values are also supplied by the actual metric units, and the acquaintance with these units should not be postponed until *after* the decimal rules have been taught.

If a pupil is thoroughly grounded in this preliminary work, he should be armed, at this stage, with—

1. Visual and concrete images of the simpler decimal values.
2. A ready ability to manipulate the simplest decimals.
3. An ability to think of such things as ·4 or ·5 of a quantity, without proceeding through the traditional path of vulgar fractions.
4. A dawning realization that decimals are simple to apprehend, and easy to manipulate and apply.

With pupils thus prepared the "rules" will present few difficulties.

Addition and Subtraction

These seldom give difficulty at any stage. The initial difficulty of the absence of zeros, as in the example—

From 3·4 take 1·762

may readily be overcome at the outset by writing the example in the form—

3·400 − 1·762

but pupils seldom experience this difficulty for any length of time.

Multiplication and Division of Decimals by Decimals

These processes are definitely the work of the Senior School, and the teaching of them is usually considered to be among the most difficult of the mathematical teacher's tasks, especially division of decimals.

Their importance cannot be denied, but may easily be overstressed, for the widespread use of "logarithms" and "slide-rules" removes the necessity for many of the elaborate calculations hitherto in vogue.

Various "rules" for multiplying and dividing decimals have long been popular with teachers, and may still be observed in regular use. Among the most widely-used of these has been that method of multiplication which consists of "marking off in the product the sum of the decimal places contained in the multiplier and multiplicand together," and that method of division which depends upon the preliminary conversion of the decimal divisor into a whole number.

These methods have several advantages: they are easy to teach, fairly easy to explain, and usually quite accurate in their application.

Of late years, however, more mathematical methods have become widespread in schools, especially Secondary Schools, and among these the so-called "standard" method seems likely to be universally adopted, both in multiplication and in division.

This "standard" method, although not openly advocated in the *Handbook of Suggestions*, is indirectly referred to and recommended in the following extracts—

> (*a*) In the multiplication of numbers of more than two digits, the process should begin with the left-hand digit of the multiplier, as this method gives the most important figures first and is specially useful in the multiplication of decimals.
>
> (*b*) In division of decimals a preliminary rough answer is readily obtained mentally, by reducing the divisor to "standard form." Thus 9·126 ÷ ·72 becomes, in standard form, 91·26 ÷ 7·2, and the approximate answer is obtained by dividing 91 by 7. If this method of division is used in written work and the quotient is placed over the dividend, beginners should have little difficulty in fixing the position of the decimal point.

The second of these two extracts indicates the basis of the method. A decimal is said to be in "standard" form when it contains only *one* digit to the left of the decimal point.

APPLICATION TO MULTIPLICATION

Example: 34·37 × ·0356.

Taking ·0356 as the multiplier, this is first expressed in "standard" form, i.e. 3·56. But if the multiplier is thus multiplied by 100, the multiplicand must correspondingly be *divided* by 100, and accordingly it now appears as ·3437.

The example is then worked as shown on the right, multiplication beginning with the left-hand figure of the multiplier. It may be observed, by inspection, that the answer to ·3437 × 3·56 must be between ·9 and 1·6.

$$\begin{array}{r} \cdot 3437 \\ 3\cdot 56 \\ \hline 1\cdot 0311 \\ \cdot 17185 \\ \cdot 020622 \\ \hline 1\cdot 223572 \\ \hline\hline \end{array}$$

APPLICATION TO DIVISION

Example: ·713 ÷ ·023.

The divisor is first expressed in "standard" form, and the corresponding correction is made in the dividend. The example, thus transformed, appears as

71·3 ÷ 2·3,

the divisor being carried out in the usual way. It is claimed by its adherents that the "standard" method is rational and safer than any other; that with its use no difficulty arises in the fixing of the decimal point in the product or quotient, and that it lends itself readily to contracted methods or to approximations, at any stage in a given example.

Applications of Decimals

As in the case of vulgar fractions, so in decimal fractions, pupils must be taught—

1. To express any concrete quantity as the decimal of another concrete quantity, and
2. To evaluate in ordinary units any compound quantity given in decimal form.

The most useful and practical examples of (1) are those which give practice in the decimalization of English money, e.g. (i) express 14s. 9d. as an exact decimal of £1, (ii) express 16s. 8¼d. as a decimal of £1 correct to 3 places.

Pupils often attain astonishing proficiency in dealing with examples of this type, but it should be remembered that mere decimalization of money is in itself of little value, unless for the purpose of making further calculations. Excellent advice in this connection is given in the *Handbook of Suggestions*—

> Decimalization of money is sometimes of great service in shortening the work in calculations of a commercial type, e.g. in finding the cost of a quantity,

given the price per unit, or *vice versa ;* in calculating compound interest and in working sums on stocks and shares.

Various "rules" for converting at sight shillings, pence, and farthings into a decimal fraction of £1, are given in textbooks, and they need not be repeated here. It should be noted, however, that the approximation resulting from counting n farthings as £·00n, with a correction of + ·001 when the number of farthings, after dealing with the last sixpence, exceeds 12, is not sufficiently accurate if the sum of money has subsequently to be multiplied by any number greater than 8, to give a correct result within a penny. In the case of large operations such an approximation may, of course, result in serious error. Since $\frac{1}{4}$d. = £·001 + $\frac{1}{12}$ of $\frac{1}{2}$ of £·001 (accurately) and therefore $\frac{n}{4}$d. = £·00n + $\frac{1}{12}$ of $\frac{1}{2}$ of £·00n, it is easy to carry out the decimalizing process to any number of places required by the particular example. (*Suggestions.*)

Readers who are interested may apply the formula just given for decimalizing money which will be found to be easy and accurate in working. It is possible, however, that pupils may find it easier to apply first principles as follows. Suppose it is required to decimalize accurately 13s. 9$\frac{3}{4}$d. The ordinary "rule" as given above would give ·675 (13s. 6d.) + ·016 (3$\frac{3}{4}$d.) or ·691.

A more accurate result may be found by continued division as follows—

Express 13s. 9$\frac{3}{4}$d. in pence, i.e. 165·75 pence. Now proceed with continued division by 12, and 20, as in ordinary reduction—

12|165·75
20|13·8125 shillings
·690625 pounds

which result is accurate, and not approximate, as in the case of the former answer obtained by "rule," i.e. ·691.

The same method of continued division may be readily applied to the decimalization of any compound quantity. We illustrate by one or two examples—

1. *Express* 11 *cwt.* 3 *qr.* 14 *lb. as the decimal of* 1 *ton.*

Starting with quarters, as the most convenient unit, we have—

11 cwt. 3 qr. 14 lb. = 47·5 quarters. Division by 4 and 20 then gives the answer—

4|47·5
20|11·875
·59375 tons. *Answer.*

2. *Express* 5 *f.* 7 *ch.* 11 *yd. as the decimal of a mile.*

5 f. 7 ch. 11 yd. = 57·5 ch.

10|57·5
8|5·75 furlongs
·71875 miles. *Answer.*

Decimals in a Technical Syllabus

It is in a Mathematical Syllabus for Technical Students that the full importance of decimals is realized, for decimals are in constant use in technical calculations of every kind, vulgar fractions being comparatively little used. Later, in such a course, the labour of the pupils in the multiplication and division of decimal quantities is considerably lightened by the use of logarithms. It is in this section of the course, and in dealing with the numerical values of trigonometrical ratios, that pupils, especially boys, become conscious of the great importance and accuracy of these decimal manipulations, but it is to be feared that many boys and most girls hardly progress far enough in the study of decimals to appreciate their great convenience in ordinary calculations.

In the later chapters of this section, especially in those dealing with logarithms and the trigonometric ratios, which involve the use of "Tables" of decimal values, the practical use and convenience of decimals will be apparent.

It will be noted that we have omitted all reference to "recurring" decimals, which are of theoretical rather than practical value. Accordingly, while pupils may learn that ·699.... is approximately equal to ·7, they need not learn elaborate rules for converting decimals such as ·699 .... to a vulgar fraction.

THE METRIC SYSTEM

It is customary to include some reference to the Metric System of Weights and Measures in every Senior School in England both for boys and for girls. The proximity of this country to the continent of Europe, and the much greater facilities for travelling which are now offered, all demand that, as part of their general education, our pupils shall have some familiarity with the Metric system in common use abroad, and shall also be acquainted with the Decimal coinages in use in the more important countries.

The traditional method by which the subject has been taught in schools is by "Table" and terminology. The "Table" was diligently committed to memory, and was then followed by copious examples in "reduction." The work was consequently highly theoretical and artificial, and left but little impression upon the minds of the pupils. In this connection, therefore, the warning contained in the *Suggestions* is timely—

> In every case where the metric system is taught, the pupils should acquire their knowledge by handling and using the weights and measures. Mere lip knowledge of the metric system, even of the metre, kilometre, the gramme, and the kilogramme, is of little value, and unless a practical knowledge is given it is useless to spend time in teaching the terminology. Rough approximations, such as that a metre is the length of a dual desk, two decimetres is the length of a span, and a centimetre is the radius of a sixpence, are well worth making and remembering by the pupils.

The advice is clear. Word-knowledge is useless. Unless the pupils know the units as *realities*, most of the teacher's labour is in vain.

The exercises set will follow straightforward lines, and the teacher should remember that practically every type of exercise set in connection with English Weights and Measures has its counterpart in the metric system.

But far more important to English pupils than the mere manipulation of metric quantities are the numerical relations of these units to the corresponding English units. These accordingly must figure largely in every syllabus. We shall therefore proceed to examine a few of these corresponding units in some detail.

Length

The usual connections which are emphasized are—

1. 1 in. = 2·54 cm.
2. 1 metre = 39·37 in.
3. 1 kilometre = ·621 mile.

From these, various other connections may easily be deduced—

Thus we may easily express 1 cm. as the decimal of 1 in., or 1 yd. as the decimal of 1 metre.

More approximate relations, useful in rough mental approximations, are—

10 cm., or 1 dm. = 4 in.
100 metres = 110 yd.
8 kilometres = 5 miles;

while a kilometre has been excellently described as "a good ten minutes' walk."

Weight

Here, while grammes are important for small scientific measurements, the ***kilogram***, for all ordinary purposes, is the important unit. The important relation is—

1 kilogram = 2·2 lb.,

from which we may deduce the simple relation that 5 kilograms are equal to 11 lb. Further, it follows that 1,000 kg. are equal to 2,200 lb., which is 40 lb. less than 1 ton. Finally, therefore, it may be deduced that—

55 English tons are equal to 56 metric tonnes (1 tonne = 1,000 kg.).

Capacity

The most useful link here is the following—

1 litre = 1·76 pints, or more simply and approximately—

4 litres = 7 pints.

From the former, we may deduce that—1 litre = ·22 gallons, or that—50 litres = 11 gallons.

Other Correspondences

Other correspondences may be worked out as required. Thus, taking 8 kilometres as equal to 5 miles, we may deduce that 64 square kilometres are equal to 25 square miles. By further deduction we have that

$$\frac{\text{1 square mile}}{\text{1 square kilometre}} = \frac{64}{25}$$

whence it follows that a population of 64 per square mile may be interpreted as 25 per square kilometre.

Straight-line Graphs Connecting Metric and English Measures

In discussing graphs later, we shall note that the above correspondences between units may readily be used as the basis of straight-line graphs for converting units of one kind to any other.

Thus, if 1 in. = 2·54 cm., it follows that 100 in. = 254 cm., and this relation may form the basis of the graph for changing inches to centimetres, and *vice versa.*

Similarly, relations such as 10 kilogram = 22 lb.; 100 litres = 176 pints, or 22 gallons; and 1,000 kilometres = 621 miles, may all be used as the basis of useful converting graphs.

Conclusion

All the above are useful, simple, and interesting aspects of the metric system, and beyond this it will seldom be necessary for teachers to proceed.

The actual use of the smaller metric units may be introduced into the Science course in a graded series of exercises in weighing and measuring.

RATIO AND PROPORTION

In dealing with Ratio and Proportion, the pupil is definitely entering upon a new and higher stage of mathematical thought. Up to this stage, he has manipulated quantities—adding, subtracting, multiplying, and dividing them—without any direct reference to their relative magnitudes. It is true that in fractions he has learned that any fraction, e.g. $\frac{1}{2}$, may be expressed in an infinite number of ways, e.g. $\frac{2}{4}, \frac{3}{6}, \frac{4}{8}, \frac{5}{10}, \frac{6}{12}$, and so on, and he has applied this knowledge to the process known as "reducing to lowest terms," but it is doubtful whether he has regarded this from the point of view of proportion. The idea comprised in the well-known terms Ratio, Proportion, Variation, is new and difficult for pupils at this age. To attempt to proceed, therefore, by definition, rule, and example, in the traditional way, is to court failure. The observations contained in the *Handbook of Suggestions* on this subject are of sufficient importance to be quoted in full—

> Sums of the kind rather quaintly called "rule of three" and more correctly styled "proportion," enter into all course of arithmetic. More and more, good teachers incline to treat all these questions by common-sense methods instead of by the method which is sometimes, if incorrectly, known as the "method of ratio." Thus, assuming that the wages of 11 men are £14 17s., and that the wages of 9 men are required, the child is no longer taught to write—
>
> $$11 : 9 :: £14\ 17s. : £x$$
>
> $$\therefore\ £x = \frac{£14\ 17s. \times 9}{11}$$
>
> but, according to the so-called "method of unity," he is trained to divide £14 17s. by 11 so as to obtain the wage of one man, and then to multiply by 9.
>
> If the "unity" stage of the above process is omitted the method becomes what is called the "fractional" method, and many teachers adopt this method from the first. Thus, assuming the wages of 6 men are £14 17s., and that the wages of 18 men are required, the child may be led in the first instance to see directly that the wages of 18 men are $\frac{18}{6}$ of £14 17s. It is a little more difficult to see that the wages of 3 men are $\frac{3}{6}$ of £14 17s. When such examples have been mastered it will be apparent that the wages of 11 men are $\frac{11}{6}$ of £14 17s.
>
> Compound proportion is nothing more than the successive application of the processes of simple proportion.
>
> Examples like these can be worked out without any reference to ratio and proportion, and any formal definition of these terms is quite out of place where children are concerned. To say this, however, is not to belittle the importance of the idea of ratio, which indeed underlies the comparison of all quantities of the same kinds. There are many valuable exercises involving this idea which are suitable for children and may lead up to more systematic teaching at some later period. The broad notion of one quantity varying either directly or inversely with another will be gained from a judicious selection of examples in graphic representation; e.g. sums about prices and quantities, distance and time, men and work, may be solved by plotting on squared paper.
>
> Again, a good illustration of proportion can be obtained by comparing the lengths of the shadows thrown by two upright rods. The teacher may begin by making the child ascertain that the shadow of a 6 ft. rod is twice as long as that of a 3 ft. rod, three times as long as that of a 2 ft. rod, and so on, and he may lead them to infer that in a general way we can obtain a comparison of the two heights from a comparison of the two shadows. Possibly he may sum up the results of his teaching by saying that the length of the shadow is proportional to the height of the post, but he will not attempt to say what proportion is or what it is not. As in other cases, the definition can convey no real meaning until the child's mind has become saturated with many examples of the thing or idea defined.

From the above it is clear that ratio and proportion is a conception which cannot, at this early stage, be taught deductively, but an idea which must be reached through copious mental and practical examples.

To the instructive example of *shadows* indicated above, we may add the equally simple subject of map-scales and scale-drawing. This is based upon the purest and simplest proportion. Every pupil will at once realize that if the scale is such that 1 in. represents 10 miles, then 2 in. represents 20 miles, 3 in. represents 30 miles, and, at the other end, ½ in. represents 5 miles, and so on.

Ample variety is possible with these simple scales, as the following examples prove.

If 1 in. represents 10 miles—

1. Draw lines to represent 20 miles, 35 miles, 65 miles, etc.

2. What distance in miles is represented by 2½ in., 3·6 in., 1 ft., etc.?

3. How many *square* miles are represented by 1 *square* inch?

Additional examples of the same type are as follows—

1. If a line of 1½ in. on a map represents 15 miles, what is the scale of the map?

2. If 2½ in. on a map represents 250 miles, draw lines on the same scale to represent 350 miles, 475 miles, etc., etc.

All the above, and similar examples, are exercises in simple proportion leading up to a clear conception of the basic idea.

Costs and Speeds

Within limits, costs and speeds offer the same possibility. Thus, if eggs are 2s. 6d. per dozen, it follows readily that the cost of 2 dozen, 3 dozen, 4 dozen, etc., is given by 2s. 6d. × 2, 2s. 6d. × 3, 2s. 6d. × 4, etc., and that the cost of 6, 4, 3, 2, etc., is given by 2s. 6d. ÷ 2, 2s. 6d. ÷ 3, 2s. 6d. ÷ 4, 2s. 6d. ÷ 6, etc. It has already been pointed out that the pupil will find more difficulty in seeing quickly that 16 eggs will cost $\frac{16}{12}$ of 2s. 6d., and it is here, accordingly, that the common-sense method of first finding the cost of a single egg may well be applied.

Copious mental examples, dealing particularly with multiples and submultiples, will be necessary at this stage. Thus, if the basis be a speed of 20 miles an hour, we shall require rapid answers to examples such as the following, worked mentally—

1. How long will it take to travel 40 miles, 60 miles, 100 miles, etc., at this speed?

2. How far will a man travel in 2 hours, 4 hours, 1½ hours, 2¼ hours, etc., at this speed?

3. How long will it take to travel 1 mile, 5 miles, 10 miles, 4 miles, etc., at this speed?

4. How far will a man travel in 3 minutes, 6 minutes, 12 minutes, etc., at this speed?

But sooner or later the general type of example must be faced. This may well be illustrated by an example such as the following—

If 9¼ yd. cost £2 6s. 3d., what will 6¾ yd. cost at the same rate?

For most pupils this will be approached through the medium of the cost of 1 yd., i.e.—

$$\begin{array}{rl} \text{Cost of } 9\tfrac{1}{4} \text{ yd.} & = \pounds 2\ 6\text{s. } 3\text{d.} \\ \text{,,} \quad \text{,,}\ 1 \ \text{,,} & = \dfrac{\pounds 2\ 6\text{s. } 3\text{d.}}{9\tfrac{1}{4}} \\ \therefore \ \text{,,} \quad \text{,,}\ 6\tfrac{3}{4} \ \text{,,} & = \dfrac{\pounds 2\ 6\text{s. } 3\text{d.} \times 6\tfrac{3}{4}}{9\tfrac{1}{4}} \end{array}$$

which by ordinary calculation = £1 13s. 9d.

It is doubtful whether more than a minority of the pupils in a class would be able to dispense with the intermediate line in the above example, and to proceed directly to the answer as being $\frac{6\frac{3}{4}}{9\frac{1}{4}}$ of £2 6s. 3d.

The normal pupil will rightly proceed through the unit line, i.e. by the Method of Unity.

Still more difficult for ordinary pupils is the "all-money" example, e.g.—

The rates paid on £18 10s. came to £7 4s. 11d. What rates would be paid on £25 at the same time?

Here the answer, on the fractional method, is clearly £7 4s. 11d. × $\frac{25}{18\frac{1}{2}}$, but most pupils would find it necessary to proceed with the ordinary three lines as follows—

$$\begin{array}{rl} \text{Rates payable on } \pounds 18\ 10\text{s.} & = \pounds 7\ 4\text{s. } 11\text{d.} \\ \text{,,} \quad \text{,,} \quad \text{,,}\ \pounds 1 & = \pounds\dfrac{7\ 4\text{s. } 11\text{d.}}{18\tfrac{1}{2}} \\ \text{,,} \quad \text{,,} \quad \text{,,}\ \pounds 25 & = \pounds\dfrac{7\ 4\text{s. } 11\text{d.} \times 25}{18\tfrac{1}{2}} \\ & = \pounds 9\ 15\text{s. } 10\text{d.} \end{array}$$

Inverse Proportion

This interesting topic may be approached by methods similar to those indicated above, for dealing with Direct Proportion.

Numerous examples of a simple kind should be explored by means of rapid mental work. In this connection it is not necessary to confine the examples to the traditional types of men and work, beseiged garrisons and food, horses and hay, and others.

Rates and times in connection with speed give excellent practice.

Example. *Suppose a distance of 120 miles. Now tabulate speeds and times as follows—*

Speed in Miles per hour	Time in hours
10	12
12	10
20	6
30	4
40	3
60	2

From these the pupil will see clearly that, as the rate increases, the time taken decreases. He may also note the most important fact that the *product* of these two varying quantities, time and rate, remains constant.

As another example, we may take the area of a rectangle, and tabulate corresponding values of two adjacent sides.

Example. *Area* = 24 *sq. ft.*

Tabulating corresponding sides, we have—

One Side	Adjacent Side
2 ft.	12 ft.
3 ,,	8 ,,
4 ,,	6 ,,
6 ,,	4 ,,
8 ,,	3 ,,

from which the same deduction of *inverse* variation may be made.

These examples may be multiplied indefinitely and are all particular instances of the simple algebraic expression—

$$xy = \text{constant, or } y = \frac{\text{constant}}{x}.$$

Where pupils have acquired some facility in the use of squared paper and the drawing of graphs, they should be required to plot, to a convenient scale, the curve $y = \frac{1}{x}$ for positive values of x, and this curve will convey to them the whole theory of Inverse Proportion.

In connection with both Direct and Inverse proportion it should be noted that, for any given statement, two converse examples are always possible.

Examples

Direct Proportion.

1. Statement.

A man walked at the rate of 4½ miles per hour.

Questions.

(i) How far would he walk in 2½ hours at this rate?

(ii) How long would he take to walk 15 miles at this rate?

2. Statement.

The cost of 3½ yd. of material was 11s. 8d.

Questions.

(i) What would 6 yd. cost at this rate?

(ii) How many yards could be bought for £1 5s. at this rate?

Inverse Proportion.

1. Statement.

A motorist travelled a certain distance in 2½ hours at 36 miles an hour.

Questions.

(i) How long would be have taken at 24 miles per hour?

(ii) At what speed could he have done the journey in 3 hours?

2. Statement.

A boat took 12½ days to make a voyage at 16 knots.

Questions.

(i) How long would it have taken travelling at a speed of 12 knots?

(ii) At what speed in knots must it travel to perform this voyage in 10 days?

In all the above, and in similar examples, the "fractional" method should be applied, where possible.

Thus, taking the examples just given—

Direct Proportion.

(i) (*a*) Answer is clearly $(4\frac{1}{2} \times 2\frac{1}{2})$ miles.

(*b*) Answer is $\frac{15}{4\frac{1}{2}}$ hours.

(ii) (*a*) Answer is 11s. 8d. $\times \frac{6}{3\frac{1}{2}}$.

(*b*) Answer is $\frac{\text{£1 5s.}}{\text{11s. 8d.}} \times 3\frac{1}{2}$.

Inverse Proportion.

(i) (*a*) Answer is $\frac{36}{24}$ of $2\frac{1}{2}$ hours.

(*b*) Answer is $\frac{2\frac{1}{2}}{3} \times 36$ miles per hour.

(ii) (*a*) Answer is $\frac{16}{12}$ of $12\frac{1}{2}$ days.

(*b*) Answer is $\frac{12\frac{1}{2}}{10}$ of 16 knots.

Compound Proportion

As we have indicated in the quotation from the *Suggestions* given above, Compound Proportion involves no new principles, and all examples can be solved by repeated application either of the "Unity" method, or of the "Fractional" method.

Graphic Proportion

We have already mentioned that proportion offers a fine field for graphic representation. Pupils soon grasp the fact that every case of direct proportion results in a straight-line graph, if corresponding quantities are plotted on square paper.

Among the related quantities which may thus be shown on squared paper we may mention the following—

1. Quantities and Costs.
2. Distance and Time at uniform speeds.
3. Mileage and Fares.
4. Wages and Hours (piece-work).

Other cases, in which the proportion is not always simple "straight-line" proportion, are mentioned in the *Suggestions*, in connection with Graphs as follows—

> It is easy to construct a diagram which may be used as a ready-reckoner, e.g. one which will give the square or square root of any number within a given range, or the relation between the side and area of similar triangles, or the relation between "cost price" and "selling price" for any particular percentage of profit.
>
> Graphs may also be used for the solution of problems in proportion, e.g. problems about trams passing or overtaking one another. As examples of graphs illustrating inverse proportion, the scholars may plot the number of revolutions per second made by a pulley connected up to another pulley of varying diameter, or may show how the time taken to dig a ditch varies with the number of men employed.

There is one particular graphical exercise which should appear in every syllabus having a technical or industrial bias, and that is process of testing a series of connected quantities for proportionality, i.e. for determining the "law" or formula connecting the quantities. This is a process which is frequently required in technical and engineering mathematics.

The quantities are usually obtained from experiment, and are then carefully plotted. If direct proportionality holds, then the quantities (allowing for experimental errors) will lie approximately along a straight line.

The further exercise, that of determining the value of the constants, a and b, in the law or formula, $y = ax + b$, should not be beyond Senior School pupils in their last year of work.

If the proportion is simple and inverse, then the plotting of corresponding values of x and $\frac{1}{y}$ or y and $\frac{1}{x}$ should yield a straight line.

Proportionate Division

Proportionate Division is a process closely dependent upon the idea of Proportion, and must be included in all ordinary Senior School syllabuses. It is a conception and a process which is at once simple, precise, and interesting, and is capable of yielding innumerable interesting exercises, both in arithmetic and in geometry.

The simple case is exemplified by the following—

Divide 60 (*or* £1 *or* 1 *yd., etc.*) *in the ratio* (*or proportion*) 1 : 2.

The actual ratio may be disguised in various ways. Thus, the above may be worded as follows—

(*a*) *Divide* 60 *into two parts so that one part is twice the other part, or*

(*b*) *Divide* 60 *into two parts so that one part is half the other part.*

(*c*) *Divide* £1 *between two boys so that for every shilling one boy has, the other has* 6*d*.

(*d*) *Divide* £1 *between two boys so that for every penny one boy has the other has twopence.*

The usual method of approach to examples of this kind is through the medium of fractional parts. Thus, in all the above examples, where the ratio is 1 : 2, the pupil is taught to give the actual parts as

$$\left(\frac{1}{1+2}\text{ and }\frac{2}{1+2}\right)\text{ or }\left(\frac{1}{3}\text{ and }\frac{2}{3}\right)$$

Problems in proportionate division are of astonishing variety, and will be found in any good textbook or classbook, such as the writer's *Common-Sense Arithmetics for Senior Boys* and *for Senior Girls* (separate series).

The equally interesting topics of Proportionate Division performed graphically and geometrically, and the general subject of Similarity in its relation to proportionate division, will be more fully discussed in the chapter of this section dealing with Geometry in the Senior School.

PERCENTAGE

> The necessity for reducing fractional amounts of a quantity to the same denominator in order to compare their values should lead children to appreciate the advantage of choosing 100 as the standard denominator and so expressing a fraction as a percentage. The term "per cent" is in everyday use, and the need for calculating percentages is frequent. Children, therefore, should be trained to express one length, sum of money, etc., as a percentage of another length, sum of money, etc., and to evaluate a given percentage of a given quantity. (*Suggestions*).

The Basic Idea

Percentage is obviously closely related to proportion on the one hand, and to fractions and decimals on the other. This point is recognized in the *Suggestions* where, in the paragraph dealing with Decimals, it is stated that pupils "should be thoroughly familiar with the equivalence of such quantities as $\frac{3}{4}$, ·75, and 75 per cent."

These indicate a simple beginning which may be made with an example of the following kind—

In a box of oranges, one in every ten was bad. How many was this per hundred (or per cent)?

From this, we may proceed to manipulate actual percentages, by extending the above to "and what per cent were good," requiring the subtraction of 10 per cent from 100 per cent. In dealing with these simple percentages the pupil should become familiar with all the more common correspondences, e.g.—

$5\% = \frac{1}{20} = \cdot05$
$10\% = \frac{1}{10} = \cdot1$
$12\frac{1}{2}\% = \frac{1}{8} = \cdot125$
$20\% = \frac{1}{5} = \cdot2$
$25\% = \frac{1}{4} = \cdot25$
$33\frac{1}{3}\% = \frac{1}{3} = \cdot333\cdots$
$50\% = \frac{1}{2} = \cdot5$
$75\% = \frac{3}{4} = \cdot75$

and constant practice in proceeding from one to the other of these is desirable. Too often, in the past, this practice has been confined to the change from percentages to vulgar fractions and *vice versa*, but children to-day should be able to recognize readily that ·145 is 14½ per cent, without recourse to vulgar fractions.

The two principal operations involved are indicated in the extract from the *Suggestions* which is placed at the head of this section. They are—

1. Finding a given percentage of a given quantity.
2. Expressing one quantity as the percentage of another quantity.

1. *Calculating Percentages of Quantities*

Example: Find 35 per cent of £1 17s. 6d.

This, traditionally, would be solved by the fractional method, i.e. 35 per cent would be expressed as $\frac{35}{100}$ or $\frac{7}{20}$, and $\frac{7}{20}$ of £1 17s. 6d. would then be found. ($\frac{7}{20}$ is most easily calculated as follows: $\frac{1}{20}$ of £1$\frac{7}{8}$ = 1$\frac{7}{8}$s. = 1s. 10½d. Hence $\frac{7}{20}$ = 1s. 10½d. × 7 = 13s. 1½d. *Answer.*)

The same result could have been more readily obtained by practice, thus—

	£	s.	d.	
	1	17	6	
25% = $\frac{1}{4}$		9	4½	
10% = $\frac{1}{10}$		3	9	
35%		13	1½	*Answer.*

Practice methods should be applied wherever possible to calculations of the above kind.

The inverse type of this straightforward calculation is more difficult.

Example. 35 *per cent of a sum of money is* 13s. 1½d. *What is the original sum?*

By the method of unity, the answer is given by

$$\frac{13\text{s. }1\tfrac{1}{2}\text{d.}\times 100}{35}$$

By the fractional method the answer is—

13s. 1½d. × $\frac{20}{7}$.

By decimals, the answer is 13s. 1½d. ÷ ·35. No rigid 'rule' for these inverse calculations should be taught, but pupils should be encouraged to apply common-sense methods suitable to each particular example.

Increase and Decrease per cent

Closely allied to the above calculations is the subject of Increase and Decrease per cent. This may conveniently be introduced by copious mental and written examples of the following type—

(*a*) *Increase* 1,250 *by* 10 *per cent of itself* (1,250 + 125 = 1,375.)

(*b*) *Decrease* £2 10*s. by* 5 *per cent of itself.* (£2 10*s.* – 2*s.* 6*d.* = £2 7*s.* 6*d.*)

Here, again, Practice methods should be employed, wherever possible.

The inverse examples allied to the above are more in the nature of problems, e.g.—

(*a*) *A village increased in population, in the period* 1921 *to* 1931, *from* 3,450 *to* 3,795. *What was the increase per cent?*

(*b*) *A man's wages were reduced from* £3 5*s.* *to* £3 1*s.* 9*d. What was the reduction per cent?*

These problems lead directly to that type of problem, so popular with teachers and textbook makers, known as Profit and Loss. Possibly too much attention has been devoted to this aspect of Percentage, though it offers a fine field for interesting problems. The elements of such problems are three in number, viz. Cost Price, Selling Price, Percentage Gain or Loss (the latter being usually reckoned in the textbooks as the basis of the Cost Price). These three elements lead to three distinct problems, for we may be asked to find either Cost Price, or Selling Price, or the Percentage Gain or Loss.

We give examples of all three—

1. A motor-car costing £250 was sold for £180. What was the loss per cent? (Loss = $\frac{7}{25}$ of 100 per cent = 28 per cent.)

2. A horse which cost 50 guineas was sold at a profit of 15 per cent. What was the Selling Price? (Selling Price = $\frac{115}{100}$ of 50 guineas.)

3. A picture was sold for 25 guineas which represented a profit of 25 per cent on its cost. What did it cost? (Cost Price = $\frac{4}{5}$ of 25 guineas.)

COMMISSIONS, DISCOUNTS, AND DIVIDENDS

These, when expressed in percentages, offer more reality than many examples in profit and loss, and accordingly exercises should be framed to deal with them.

Common discounts, such as 2½ per cent, 3¾ per cent, and 5 per cent, should be known by the simple equivalents of 6d., 9d., and 1s. in the £.

Examples should be of both the direct and inverse type.

2. *Expressing one Quantity as a Percentage of Another Quantity*

This is a process constantly required in ordinary calculations, and, accordingly, the type of exercise must receive definite attention.

Many simple cases are ready to hand. We mention but a few—

1. Percentage of children present at school.
2. Percentage of marks gained.
3. Percentage of successes and failures in an examination.
4. Percentage of boys and girls in a mixed school.
5. Percentage of seeds which germinate in a garden plot.

Many others will occur to the teacher. The fractional method is usually employed, but methods which employ decimals or practice are frequently of service.

EXAMPLES.

1. *In a regiment of* 900 *soldiers,* 135 *were killed or wounded. What percentage was left?*

Here the number left, by subtraction, is 765. The calculation required is to express the ratio or fraction $\frac{765}{900}$ as a percentage.

Division by 9 gives $\frac{85}{100}$ or ·85, which as a percentage is 85 per cent.

2. *Express* £2 14*s.* as *a percentage of* £7 10*s.*

Here the fraction is $\frac{£2\ 14s.}{£7\ 10s.}$ which reduces to $\frac{54}{150}$ or $\frac{9}{25}$ or ·36, and this clearly is 36 per cent.

Senior pupils should note carefully the close and simple relation between decimals and corresponding percentages.

Practical Applications

Applications of percentage are numerous and important. Thus the boys in the higher classes should learn in their Science lessons the meaning of *percentage composition* and *percentage error*; girls should be able to apply the idea of percentage to food analysis and food values; while both boys and girls should be able to apply percentage to geographical statistics whenever required. These real and practical applications of percentages are in the end of more lasting value to the pupil than the usual unending succession of bookish problems and puzzles.

INTEREST

Interest, viewed mathematically, is merely a commercial application of percentage, with the added factor of Time. Sums in Interest, both Simple and Compound, formerly occupied a good space in the syllabuses for the older children in Elementary Schools. In the reaction against 'sums' and 'types' and 'tricks,' the subject of Interest, in common with other commercial applications of arithmetic, was in danger of being thrown aside and totally neglected.

To-day, however, it is recognized that Interest, Simple and Compound, is an integral part of everyday life and ordinary business transactions, and accordingly the subject rightly appears in most Senior School syllabuses, especially those schools which attempt a commercial bias at the end of the course. It is the method of treatment of the subject, rather than the subject itself, which has changed materially. The older textbook gave all varieties of Interest sums with 'rules' for each, such rules being mainly dependent upon 'unity' methods or 'proportion.' To-day, the subject is treated as a straightforward *calculation* rather than as material for puzzles and problems. The emphasis in the first instance is accordingly on the teaching of the straightforward calculation of Interest, the puzzles being put aside until some familiarity with algebraic methods has been acquired, so that the ordinary formulae for Interest can be readily applied.

The Basic Idea

The basic idea of Interest should present no difficulty. Interest is an inevitable feature of all transactions in connection with Loans, Mortgages, Building Societies, Buying by Instalments, and the Pawnbroker and the Moneylender. Pupils should be familiar with such common rates as 5 per cent per annum, and should be able to construe this as 1s. per £1 per year, or 1d. per £1 per month.

Simple Interest

As soon as the fundamental idea is grasped, the pupil is ready for the calculation of Interest on any given sum of money.

EXAMPLE.

Find the Simple Interest on £375 for 4 years at $3\frac{3}{4}$ per cent.

The actual calculation requires the finding of 15 per cent ($3\frac{3}{4}$ per cent × 4) of £375, and is most conveniently performed by the method of Practice, as follows—

		£	s.	d.	
		375			
10%	$\frac{1}{10}$	37	10	–	
5%	$\frac{1}{2}$	18	15	–	
		£56	5	–	*Answer.*

The same example could, of course, be worked by the method of Unity, or by the Formula $I = \frac{P \times T \times R}{100}$, but at the outset it is best regarded as a simple calculation in percentage, performed by the method of Practice.

Pupils following a commercial course should be taught to use an Interest Table, especially when the Interest is a matter of days as well as of years.

Many teachers, however, will be unable to resist the lure of tradition, textbook, and type, and will accordingly pursue the topic much further, requiring their pupils to find such things as Principal, or Amount, or Rate, or Time, from given data. All these may be worked from first principles, or by the Formula already quoted. Too much time, however, should not be devoted to such types, for their value is theoretical and academic rather than practical.

Compound Interest

The fundamental idea is best explored by working, with the class, an example by first principles—

EXAMPLE.

Find the Compound Interest on £450 *in* 3 *years at* 4 *per cent.*

£
450 = Principal at outset
4% 18 = Interest for First Year
468 = Second Principal
18·72 = Interest for Second Year
486·72 = Third Principal
19·4688 = Interest for Third Year
506·1888 = Final Amount
450
£56·1888 = Whole Interest
= £56 3s. 9d. approx.

Later, and particularly in connection with algebraic work in the subject of Geometrical Progression, the pupil should deduce that £1 at 4 per cent Compound Interest becomes successively £(1·04), £$(1\cdot04)^2$, £$(1\cdot04)^3$, and so on, and that in consequence £450 becomes £450 × $(1\cdot04)^3$ in 3 years, whence the required Compound Interest is found by subtracting the original £450.

The final step, to the general formula I (or interest) = $P\{(1\cdot0r)^2 - 1\}$ should then be easy.

When once the formula is grasped, pupils may proceed to any calculation with the help of logarithms, though actually, in practice, a table of Compound Interest would probably be used.

ADDITIONAL WORK SUITABLE FOR THE FINAL YEAR OR TWO YEARS OF A COMMERCIAL COURSE

At the outset of this section we indicated a number of topics which, in the opinion of experienced teachers and experts, might well be omitted from courses for ordinary pupils in Senior Schools. This, however, should not be construed to mean that such topics are valueless for every pupil. They have a definite place in the higher classes of schools which aim at a definite commercial bias, as will be seen from the following extract from the *Handbook of Suggestions*—

> Schools where instruction in Principles of Commerce is given may usefully go much further than the ordinary school in dealing with commercial applications such as Discount, Foreign Exchange, Compound Interest, Annuities, and Present Worth. Data for these calculations may be obtained from the daily press, market reports, and statements of national, local, and company finances.

It is particularly important that Head Teachers who aim at a definite Commercial bias in the last year or two of the Senior School course should have regard to the requirements of the pupils where they afterwards proceed to the Courses arranged for Part-Time Evening Students in Commercial and Technical Schools and Institutes. The syllabuses of the two types of Institution should be directly related so as to enable a pupil to proceed from the Day School to the Evening School or College without overlap or omission. This is an exceedingly important function of the Senior School, and the following remarks from the *Suggestions*, though directed mainly to boy Technical Students, may equally well be applied to Commercial Students of both sexes—

> It would be an ill-service to their further instruction if those boys who passed on to Technical Schools were found to possess a merely superficial knowledge, and to be poorly equipped in the power of neat manipulation, accurate computation, and simple analysis of an ordinary problem.

As a guide to teachers who are developing a commercial bias, we give the latest syllabuses in use for Part-Time Commercial Students who are taking the well-known examinations of the Union of Lancashire and Cheshire Institutes.

UNION OF LANCASHIRE AND CHESHIRE INSTITUTES

PRELIMINARY COMMERCIAL COURSE

First Year.

(*For pupils, normally* 14–15 *attending Evening Schools for the First Session after leaving the Day School.*)

ARITHMETIC AND ACCOUNTS

Arithmetic	*Book-keeping*
1. Revision of elementary processes.	How to keep a petty cash book with analysis columns.
2. The rapid decimalization of money; and the conversion of the decimal of £1 into shillings, pence, and farthings.	
3. Application of the above and other methods to finding—	The invoice.
(*a*) Cost of a number of articles, given price per article.	Debit notes. Credit notes.
(*b*) Price per article, given cost of a number of articles.	
4. Simple areas and volumes (square root). Applications to finding cost, English weights and measures. Applications to finding cost, metric system.	The purchases book. The sales book. Returns books.
5. Discount— (*a*) As a deduction from Gross Price—Trade Discount.	
(*b*) As a consideration for payment to time—Cash Discount.	Cheques—A simple exposition of the banking system.
6. Calculation of net prices from gross prices and *vice versa*.	The cash book in three columns.

Second Year.

(*For pupils normally* 15–16.)

Arithmetic	*Book-keeping*
1. Revision of first year.	The cash book in three columns.
2. Gross profits and net profit. Calculations of gross profit and percentage of gross profit on— (*a*) Buying price;	The profit and loss accounts (introduced by concrete arithmetical examples). The records required to make up a profit and loss account.
(*b*) Selling price.	Trading account.
3. Calculations of net profit on—	Expenses account.
(*a*) Sale of a definite quantity of goods.	
(*b*) On the whole undertaking for a given period.	Records showing indebtedness by the firm and to the firm. Personal accounts. Real accounts.
4. Simple Interest.	Records showing the financial position of a business at the beginning and at the end of a trading period. Capital account. Balance sheet. Trial balance.

SENIOR COMMERCIAL COURSE

First Year.

(*For pupils normally aged* 16.)

TWO PAPERS

(Candidates must satisfy the Examiner in both papers)

PAPER I.

This paper is designed to test the accuracy and speed of the candidate in the simple rules, involving addition, subtraction, multiplication, and division of numbers and money, such as adding bills and petty cash book, balancing accounts, testing the accuracy of statements by the method of long and cross tots, decimalization and de-decimalization of money.

Twenty minutes will be allowed for this paper. The answers to the questions must be written in the spaces provided on the question paper, and the paper will be collected before Paper II is given out. If rough work is necessary it must be shown on the paper in the space provided.

PAPER II.

Ratios expressed by means of vulgar fractions, decimal fractions, percentages; the inter-relation of these three methods of expression.

Percentages developed through commission and brokerage.

Decimalization of money and other quantities.

Simple costs ascertained by (*a*) decimalization of money and "practice," and (*b*) decimalization and multiplication.

Meaning of significant figures and degrees of accuracy in arithmetical operations and application to contracted methods.

Elementary treatment of the Metric System.

Areas of rectangles, triangles and circles; volumes of rectangular solids; symbolical expression and substitution in formulae.

Cash and trade discounts and their bearing upon actual prices; profit and loss—gross and net—in relation to (*a*) selling price and turnover, (*b*) buying price, (*c*) capital involved; illustrated by simple profit and loss accounts and balance sheets.

Ascertainment of selling price from given data; calculations to ensure given return on selling price.

Expenses of a business; rent, rates, and taxes; bad debts; prepayment of insurance.

Simple costing in a manufacturing business taking into account material, wages, overhead expenses, selling costs.

Simple interest and its applications, total interest on sums of money over varying periods, involving the use of decimals and interest tables; bank interest; mean due date.

Simple calculations relating to compound interest (by arithmetical methods excluding the use of logarithms).

Graphs—their application to the representation of statistical information and to the solution of problems, such as problems involving ratios.

(*Book-keeping is a separate subject in the Senior Course.*)

The above syllabuses indicate the considered opinion, not only of experienced teachers, but also of competent representatives of the

Commercial world, and may accordingly be considered suitable for normal pupils. They should thus prove an invaluable guide to teachers in Senior Schools.

A most helpful explanatory Memorandum is issued in connection with the Preliminary Commercial Course, and this should be in the hands of every teacher of these subjects. It may be obtained from the Secretary, U.L.C.I., 33 Blackfriars Street, Manchester, at a small cost.

AVERAGES

Most syllabuses of work in Senior Schools find space for some attention to the subject of averages.

The subject is rather cursorily dealt with in the *Handbook of Suggestions*, where we find a brief reference as follows—

> The term 'average' is difficult to define, but it is in very general use, and children should become familiar with its application. Exercises which will introduce it and illustrate suggest themselves readily to all teachers; children may be trained to calculate the average attendance of a class, the average score of a cricketer, etc.

The subject is of sufficient importance to warrant somewhat more detailed treatment. The first exercises will clearly involve the calculation of the average value of a series of quantities. At the outset only addition and division will be required, 'average' being defined for practical purposes as the equal distribution of a total. Later, multiplication will be involved, as in the example—

Find the average cost per lb. of 15 *lb. at* 2*s. per lb. and* 25 *lb. at* 2*s.* 6*d. per lb.*

In the first and simplest type the work of finding the average value of a series of quantities may well be combined with graphic illustration. Thus the various quantities may be plotted to any convenient scale, and the 'average' indicated by a horizontal line in red or some contrasting colour. This provides an excellent introduction to statistical methods, and indicates clearly the deviation of the separate quantities from their average value.

The relation of the average to the total of a series is particularly interesting in the case of quantities in arithmetic progression. If we examine such a series, e.g.—

5, 8, 11, 14, 17, 20, 23

we note that the average value (in the case of an odd number of terms) is always the middle term (i.e. 14). Further, the terms balance in pairs round this middle term, i.e. $11 + 17 = 28$, $8 + 20 = 28$, and $5 + 23 = 28$, the sum in each case being twice the average value. The same is true for an even number of terms, except that the average value lies half way in value between the two middle terms, e.g. in the series 5, 8, 11, 14, 17, 20, the average value lies halfway in value between 11 and 14, i.e. $12\frac{1}{2}$, which again is equal to half the sum of 8 and 17, or of 5 and 20.

It follows that the average value of any arithmetical series may be written down as half the sum of the first and last terms, or in the usual algebraic notation: $\dfrac{a + l}{2}$. From this we have at once the formula for the sum of an arithmetic series, which may be expressed in words as Sum = (No. of terms) × (Average Value) or in symbols as $s = \dfrac{n(a + l)}{2}$.

In the case of the first n natural numbers, this formula becomes simply: $s = \dfrac{n(n + 1)}{2}$. These formulae are not beyond the capacity of the best pupils in the later years of a Senior School Course.

Having dealt in considerable detail with the more arithmetical parts of the syllabus, including the strictly commercial aspects, we shall now devote considerable space to a discussion of the more definitely mathematical, as contrasted with the purely arithmetical, aspects of the subject, and shall incidentally, we hope, indicate quite clearly the possibilities of the subjects of Mensuration, Algebra, Geometry, and practical mathematics of various kinds, both for boys and for girls.

THE IMPORTANCE OF A MORE MATHEMATICAL VIEW OF ARITHMETIC

WE have indicated in the opening paragraph of this section the opinion, so definitely expressed in the *Hadow Report*, that it is necessary that the mathematics of the new Senior Schools shall be completely revalued; that much of the traditional lumber of pure arithmetic may profitably be discarded, and that the time so saved may well be employed in developing the more mathematical side of the subject.

This opinion is fully supported by the later *Handbook of Suggestions to Teachers*, from which we may quote the following—

> (*a*) To a large extent the teaching should be concerned with elementary notions of shape, size, and weight, rather than with abstract number; in other words, it is applied and concrete arithmetic, rather than abstract arithmetic, which must be taught.
>
> (*b*) With the extension of the leaving age and the spread of Central Schools it is no longer necessary to limit too strictly the extent to which the study of mathematics may be carried in schools where circumstances are favourable. It does not follow that the treatment of the subject will be similar to that adopted in the case of Secondary School pupils of the same age. In the one case the syllabus will be influenced by the fact that the scholar will enter on his life's work at the age of 15 or 16 at the latest, and in the other will be governed by the expectation that two or three additional years of school life will remain during which the study of the subject may be further developed.

The *Hadow Report* supports this view at greater length as follows—

> There is little doubt that the mechanical, lifeless, and abstract treatment of arithmetic which has been so common in the past has produced for many a distaste for the subject which has persisted throughout life. There is need, therefore, for more vivid, more logical, and more practical methods in teaching the subject, methods which will cause the pupil to appreciate both the beauty of mathematical truths and their practical applications. If mathematical teaching is to be satisfactory there must be recognition of the two aspects of mathematical truths. On the one hand are the abstract relations which these truths have between themselves, and on the other are relations to realities outside themselves. Thus, in the early history of mathematics a study of the geometrical properties of similar triangles enabled Thales to determine the height of a pyramid. The history of mathematical progress is a record of development of these two aspects of mathematical truths in close association with each other, and the view that they can exist as distinct forms of intellectual activity has exerted a harmful influence upon mathematical teaching. *Every course, therefore, should aim at developing in the pupil an appreciation of the meaning and teaching of a coherent system of mathematical ideas and the realization of the subject as an instrument of scientific, industrial, and social progress.*

In final confirmation of this desirability of a broader conception of the mathematical training possible in the Senior School we may quote from the *Handbook of Suggestions* as follows—

> In general, it may be said that the good teacher of mathematics need not hesitate to take the intelligent boy outside the beaten path if the steps are made intelligible from first principles and if the work is given a practical application within his ken. The chief value of such work is to give the pupil a glimpse of what lies beyond and thus to invest his routine work with a new meaning. In this way a taste may be created for further study, but it would be an ill service to their further instruction if, as a result, those boys who passed on to Technical Schools were found to possess a merely superficial knowledge and to be poorly equipped in the power of neat manipulation, accurate computation, and simple analysis of an ordinary problem.

Having thus quoted our authority for widening the scope of the mathematical syllabus in Senior Schools, we shall now discuss in considerable detail the various branches of Elementary Mathematics which may profitably be introduced, such as Mensuration, Geometry, and Practical drawing, Algebra and Graphs, and Numerical Trigonometry.

RIGHT-LINE FIGURES

Mensuration

Mensuration may be defined as the application of arithmetic to lines, areas, and volumes. These applications have rightly been long considered as very important in schools. In the words of the *Suggestions*—

> Calculations as to lengths, areas, and volumes have to be undertaken in every walk of life, and they also have bearing on the economy of the home. Although, chiefly because of the greater amount of time available for the subject, mensuration is commonly developed more in Boys' Schools, there is no reason to regard it as unsuitable for girls: certain common applications such as "papering" and "carpeting" sums are even more applicable in their case.

Before discussing the actual topics suitable for a Mensuration syllabus, we may first remark upon the general methods of teaching which should be adopted. The traditional method was largely mechanical and almost purely deductive. Rules and formulae were memorized; little or no attempt was made to demonstrate or prove the truth of such formulae; and the usual lesson consisted of the working of 'sums' based upon the formulae. The work was thus mainly mechanical, seldom practical, and generally dull. Modern methods, by contrast, insist that the rules and formulae shall, as far as possible, be discovered and founded upon the pupil's own practical work in drawing and measurement. The method may be slightly slower at the outset, but the enormous gain in interest and intelligence is more than worth the extra time required. So, too, modern teachers attempt to make the applications of the formulae, when learnt, as real and as practical as possible. Here it may be observed that the teachers are but imitating the practice of ordinary people in their later life, where the usual procedure involves the actual collection of data before any calculation is made, as contrasted with the school procedure where all the data required are usually supplied by teacher or textbook. In ordinary life a mensuration problem usually has several aspects, e.g.—

1. The collection of the necessary data (usually accomplished by careful measurement).
2. The making of a freehand sketch, with measurements inserted.
3. The construction, where necessary, of a more accurate drawing to scale, from particulars obtained under 1 and 2.
4. The final calculations of quantities and costs involved.

The ideal teaching of mensuration will involve most, if not all, of these points, even though pressure of time in schools prevents attention being thus given to all the aspects of each particular problem—in the words of the *Suggestions*—

> It would be too much to say that all mensuration problems should be based upon data which the children have obtained for themselves, but the most instructive problems are undoubtedly those suggested by the children's practical work.

Two other general principles need emphasis. In the first place, all mensuration calculations and problems, where possible, should be illustrated by drawings and diagrams made by the pupils. If this is a regular practice, the solution of an example or problem is frequently indicated at once, while the answer obtained can be checked by reference to the diagram, and double-checked, if necessary, by alternative methods of calculation. Too much time need not be spent upon these illustrative diagrams, and only occasionally will it be necessary to draw such diagrams strictly to scale. In the second place, new formulae should be explored and demonstrated, wherever possible, by practical methods, before being committed to memory—

> Thus by means of paper-cutting scholars may verify or discover for themselves the relation between the area of a triangle and that of the rectangle on the same base and having the same altitude, and may thus arrive at the formula for the area of the triangle. The relation between the volume of a cone and that of a cylinder having the same height may be verified by using a cone which fits accurately into a cylinder. The contents of the empty cylinder may be ascertained by means of a graduated measuring jar and compared with its contents after the insertion of the cone. Or the weights of sand which the cylinder will hold before and after the insertion of the cone may be compared, or, again, the volumes of water which solid cones or cylinders will displace may be compared, or the weights of accurately made cones and cylinders of the same metal may be compared. In similar ways the relation between the volume of the sphere and that of the circumscribed cylinder can be verified. (*Suggestions*.)

Finally, as a last general principle, it is necessary to emphasize that the calculations and problems set should have a definite reference to reality—

> Plenty of material for mensuration problems is always forthcoming. The apparatus required for these exercises will be simple, and much of it is already to be found in the majority of schools. The classroom will furnish many suitable objects, and it is easy to obtain such things as metal washers and nuts, small pieces of piping, plates and balls, so that each child may have something to measure for himself. It may be noted that the provision of callipers will widen the range of measurement which can be made with a reasonable degree of accuracy. Some measurement of larger objects out of doors can be done by most schools, and in the country such things as stacks, sheds, clamps of potatoes, and timber, will afford excellent practice." (*Suggestions.*)

It will thus be noted that Mensuration can no longer be regarded as an isolated subject, to be treated only through the medium of *sums* in the Arithmetic lesson, but must be related to other subjects such as Handwork, Science, and Geography, with the measurement and practical drawing exercises appropriate to each.

Rectangular Area

The basis of Elementary Mensuration is the subject of rectangular area, and the necessary formula is—

Area = Length × Breadth, where length and breadth are expressed in similar units, the resultant area in consequence being given in square units of the same kind.

If the pupil has passed through an appropriate course in a good Primary School before the age of 11, the subject is not new, and much preliminary work will already have been done. Thus the pupil on entry to the Senior School may presumably be familiar with the following—

1. The square inch, square foot, and square yard (explored by actual drawing and measurement, including paper cutting).
2. The determination of the simplest rectangular areas, and the representation of such areas to simple scales, where necessary, in reasonably accurate drawings.

These fundamental points will, of course, need revision at the outset, but the pupil should soon be ready for further developments of rectangular area appropriate to the Senior School.

It is usual, in the early stages, to devote much attention to rectangular area in connection with the home. Examples here are unlimited. We indicate a few of the more common—

DOMESTIC INTERIORS

1. Walls—papering and colouring.
2. Floors—carpeting, staining, polishing.
3. Ceilings—white-washing, papering.
4. Picture-rails, friezes, dadoes.
5. Doors, windows.
6. Fireplaces, hearths.
7. Stairs and landings.
8. Halls and passages.
9. Pictures, curtains.

DOMESTIC EXTERIORS

1. Walls, washing and painting.
2. Roofs, roof-coverings.
3. Gates and fences.
4. Gardens and Flower-beds.
5. Lawns and Paths.
6. Outhouses.
7. Glass-houses, 'Lights.'
8. Yards and their paving.
9. Garden walls.

The above topics provide ample exercises in rectangular area, and are suitable alike for boys and girls. They are at once both mathematical and useful in the usually accepted sense, and should accordingly be included in all general syllabuses for the first two years of a Senior School course. Their reality will be increased if the calculations include, where possible, the probable *cost* of the operation of papering, painting, tiling, etc.

Further, the practical nature of these topics renders them easily adaptable to the modern method of "projects." Thus a class of girls has been known to carry out successfully the whole decoration and furnishing of a teachers' room with the minimum of assistance, taking all the necessary measurements, preparing the necessary plans and simple specifications, and arriving at a satisfactory estimate of the total cost. Work of this kind has advantages which need not be elaborated.

If additional examples are needed, either for practical work or for "sums," these are at hand in the School, the School playground, and School garden, where projects and problems involving rectangular area are of infinite variety.

In the actual work of calculation, the examples will obviously not be all of the direct order, i.e. it will frequently be necessary to determine either length or width from particulars supplied. These processes will introduce the pupil quite naturally to that useful device known in Algebra as "Changing the subject of a formula." The formula here used is—

$$A = l \times b,$$

and by "changing the subject," we evolve two other expressions—

$$\text{(i)}\ l = \frac{A}{b}$$

$$\text{(ii)}\ b = \frac{A}{l}$$

which are in constant use in calculation.

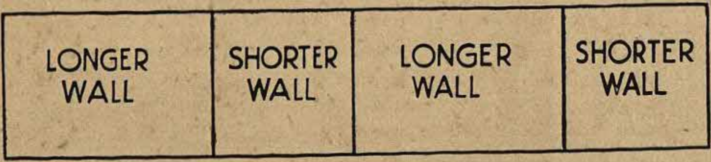


FIG. 1

Cardboard Box used to Demonstrate Area of Walls

We add a few notes on the topics outlined above.

The Walls of a Room

The calculation of the area of the four walls of a room frequently presents some difficulty, but may readily be demonstrated by opening out the four sides of a cardboard box, as shown in Fig. 1 (above).

The four walls are then seen to form one rectangle, the length of which is equal to the distance round the room, and the width of which is equal to the height of the room. Hence the total wall-area is given by—

Distance round room × Height,

or in symbols—

$$2\,(l + b)\,h$$

In connection with 'papering' problems, it is useful to note that the standard 'piece' of wallpaper in this country has an area of 12 yd. × 21 in. This area is 7 sq. yd. Hence the number of 'pieces' required for a room is given, in theory, by dividing the wall-area (in square yards) to be papered, by 7. In practice, of course, due allowance must be made for waste due to "matching the pattern" of the strips, and other unforeseen factors.

Carpets

Carpets to-day are frequently of the seamless variety, made to a series of standard lengths and widths, and seldom covering the whole of the floor of a room. Useful calculations may accordingly be set, involving the finding of the area of the uncarpeted borders and spaces, and the cost of staining and polishing such borders. Where it is proposed to cover the whole of a floor it should be remembered that such coverings are frequently sold in standard widths at a cost per linear yard, and in consequence the necessary length of covering must be found from the principle—

$$\text{Length required} = \frac{\text{Total area to be covered}}{\text{Width of material used}}$$

Gardens, Borders, Lawns, Paths

Examples based on these topics usually involve the finding of partial areas, as represented by the shaded parts of the following diagrams—

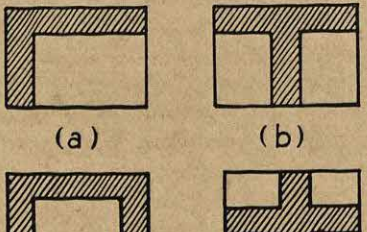


FIG. 2

Partial Areas

Of these, examples of type *c* are probably the easiest, and of type *d* the hardest.

All these partial areas can, however, be calculated in two alternative ways, a fact which is most useful for purposes of checking. They may either be calculated directly, as the *sum* of a series of rectangular areas, or indirectly, as the *difference* between the whole area and the part or parts of the area which are not shaded.

In setting examples of this type it is fair that every example shall be illustrated by a dimensioned diagram, and shall not be merely described in words. Such a diagram not only makes the example more real and practical, but enables additional exercises to be set based upon the same diagram. The possibilities of this diagrammatic method will be clearly seen in the various books of the new *Common-sense Arithmetic for Senior Boys*, by Potter and Bamford (Pitman). We give below (Figs. 3 and 4) two sets of exercises taken from these books.

All these diagrams, and similar ones, may, if necessary, be drawn to a suitable scale. Thus it will be seen that diagrams add immensely to the interest and value of the examples.

The Mensuration of the Square

The Square is a particular type of rectangle which presents but little difficulty. A wide variety of exercises is possible, which we can best illustrate by a series of examples. Our work may take any of the following forms—

1. *Find the area of this* (*or that*) *square.* (*No measurements supplied.*) This is a real all-practical example, the value of the answer

From Book I (for pupils aged 11 to 12).

AREA—GARDENS AND PATHS

(1) In Fig. 1, find—
- (*a*) The width of the path.
- (*b*) The area of the lawn.
- (*c*) The area of the path.
- (*d*) The total distance round the whole garden.

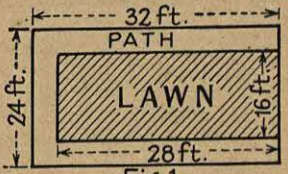


Fig.1.

(2) In Fig. 2, find—
- (*a*) The width of the path.
- (*b*) The area of the path.
- (*c*) The cost of making the path at 3s. per sq. yd.
- (*d*) The cost of the fence round the outside of the path at 5s. per yd.

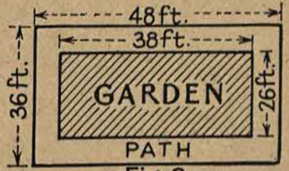


Fig.2.

(3) In Fig. 3, the path is everywhere 4 ft. wide. Find—
- (*a*) The area of the whole garden.
- (*b*) The total area used for roses.
- (*c*) The area of the paths.
- (*d*) The total length of edging needed for the paths.

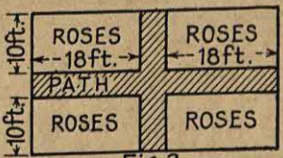


Fig.3

(4) In Fig. 4, find—
- (*a*) The area of the whole garden.
- (*b*) The total area used for flowers.
- (*c*) The area of the lawn.
- (*d*) The cost of making the lawn at 9d. per sq. ft.

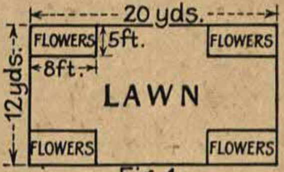


Fig.4.

(5) In Fig. 5, find—
- (*a*) The area of the garden.
- (*b*) The total distance round the edge of the garden.
- (*c*) The number of 6-in. edging tiles needed to make this edge.
- (*d*) The cost of levelling the garden at 1s. 6d. per sq. yd.

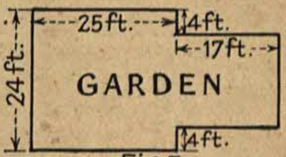


Fig.5.

(6) In Fig. 6, the paths (shaded) are everywhere 6 ft. wide. Find—
- (*a*) The area of each vegetable plot.
- (*b*) The total area of the paths.
- (*c*) The cost of fencing the whole garden at 1s. per yd.
- (*d*) The cost of edging the vegetable plots at 3d. per ft.

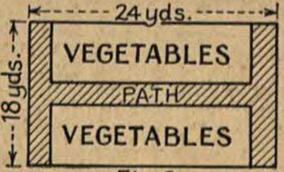


Fig.6.

FIG. 3

Gardens and Paths

From Book II (for pupils aged 12–13).

AREA

(1) Fig. 1 represents the plan of a room.
(a) Find the area of the room.
(b) Find the total distance round the room.
(c) Find the area of the biggest wall, if the room is 10 ft. high.
(d) Find the size of the largest square carpet that could be laid in the the room.

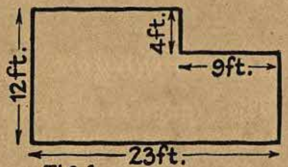


Fig. 1.

(2) Fig. 2 represents a floor partly covered by a carpet.
(a) Find the area of the carpet.
(b) Find the area of the room.
(c) Find the area of the border not carpeted.
(d) Find the cost of the carpet at 7s. 11d. per sq. yd.

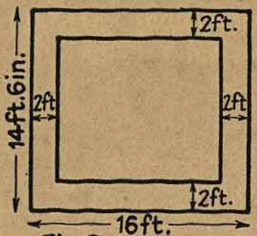


Fig. 2.

(3) Fig. 3 represents a made-up carpet, consisting of two strips lengthwise in the centre, and a border round, which is everywhere 1 ft. 6 in. wide.
(a) Find the width of each strip.
(b) Find the length of each strip.
(c) Find the total area of the border.
(d) Find the cost of the whole carpet at 9s. 6d. per sq. yd.

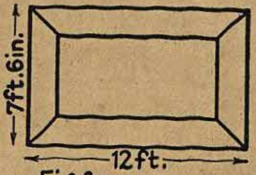


Fig. 3.

(4) Fig. 4 represents a wall with a fireplace.
(a) If the fireplace is 4 ft. 6 in. wide, what width is left on either side of the fireplace?
(b) Find the total area of the fireplace, if it is 4 ft. high.
(c) Find the remaining area of the wall which is not taken up by the fireplace.
(d) What is the largest square mirror that could be placed above the fireplace?

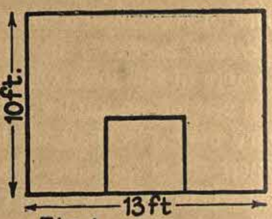


Fig. 4.

(5) Fig. 5 represents a door having four panels.
(a) If the width of the wood outside the panels is everywhere 3 in., find the width of each panel.
(b) If each of the top panels is 3 ft. 6 in. long, find the length of the bottom panels.
(c) Find the area of one top panel and one bottom panel.
(d) Find the cost of polishing each side of the whole door at 1s. per sq. ft.

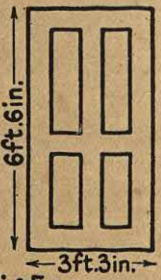


Fig. 5.

FIG. 4

Rooms, Walls, and Floors

depending entirely upon the accuracy of the measurements made.

2. *Find the area of the square whose side is* ——. (Calculation.)

3. *Find the real area of a square represented in a diagram drawn to scale.* (Practical.)

4. *Find the area of a square whose perimeter is* ——.

5. *Find the side of a square whose area is* ——. (This involves the finding of square roots by factors, or by 'rule,' or by logarithms, according to the age and ability of the pupil.)

The above are the basic problems, but they may be extended and varied as much as is desired. We add a few variations—

6. *A square of 1-ft. side is ruled in squares of*

2-in. side. How many of these squares are there?

7. *What is the cost of paving a given area with square tiles of —— in. side at —— per dozen tiles?*

8. *A square hall is covered with square tiles. There are x tiles along a diagonal. How many tiles are there altogether?* (Answer x^2)

9. *A field is twice as long as it is wide, and has an area of* 5,000 *sq. yd. What are its length and width?*

10. *A plot is three times as long as it is wide, and its perimeter is* 120 *yd. What is its area?*

Examples of the type indicated in No. 9 and No. 10 above are easily solved, if the areas are thought of as made up of a series of squares.

The Area of the Triangle

The area of a triangle follows very naturally from that of a rectangle. It has already been indicated that the relation of any triangle to its corresponding rectangle may easily be demonstrated by paper-cutting.

The method of demonstration is obvious from the following diagrams (Fig. 5)—

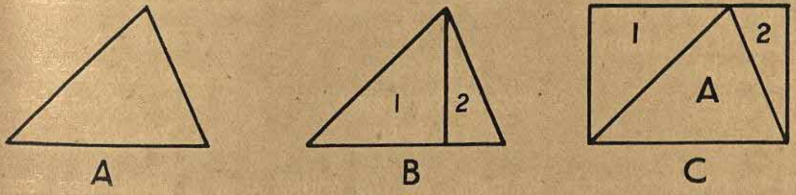


FIG. 5

Area of Triangle: Demonstration with Rectangle

Two equal triangles, *A* and *B*, are drawn and cut out in paper. One of them (i.e. *B* as shown) is cut up into two right-angled triangles (1 and 2). These are then arranged round the triangle *A* to form the rectangle shown in *C*. From this it follows that, since the area of the rectangle *C* is given by the formula $A = b \times h$, then the area of one of the equal triangles, *A* or *B*, is given by the formula—

$$\text{Area} = \frac{\text{Base} \times \text{height}}{2}.$$

Corroboration of this fact is given by the relation of any triangle to the parallelogram of the same base and altitude. It will be clear to pupils, by the ordinary methods of paper-cutting, that two equal triangles can be fitted together to form a parallelogram, as seen in *D*, *E*, and *F* (Fig. 6).

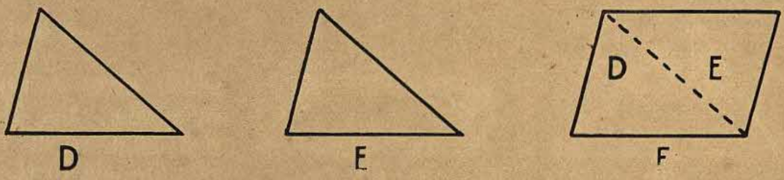


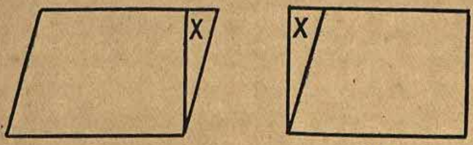
FIG. 6

Area of Triangle: Demonstration with Parallelogram

It follows, therefore, that if the area of the parallelogram is found by multiplying the base by the altitude, then clearly the area of one triangle, *D* or *E*, is found by the formula $A = \frac{1}{2}\,bh$. All that is necessary here is to demonstrate that the area of the parallelogram is equal to the area of the rectangle having the same base and altitude, which is usually demonstrated as shown in Fig. 7.

Fig. 7 (i) shows the parallelogram, from which a small right-angled triangle *x* is cut. Fig. 7 (ii) shows this small right-angled triangle transposed from right to left of the remainder of the parallelogram, converting the parallelogram at once into an equivalent rectangle.

A final exercise is here illustrated to show how a triangle may be converted by paper-cutting into an equivalent rectangle having the same base but half the altitude of the triangle (Fig. 8).

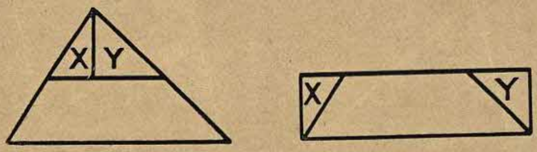


(i) (ii)

FIG. 7

Area of Parallelogram Equal to Rectangle of Same Base and Altitude

In the original triangle (see Fig. 8 (i)) a line is drawn parallel to the base through the middle point of the altitude. Two triangles are then constructed as shown (X and Y). Fig. 8 (ii) shows these two triangles X and Y cut from the triangle and re-arranged to form the equivalent rectangle.



(i) (ii)

FIG. 8

Triangle Area

These demonstrations of common formulae by means of drawing and paper-cutting are excellent for the purpose. They are easily carried out; they are convincing and effective; and they require no elaborate background of mathematical theory.

Changing the Subject of the Formula $A = \frac{1}{2} bh$

As soon as the formula is grasped, it is necessary, as has already been pointed out in the case of the rectangle, that the pupils shall be able readily to change the subject of the formula. Thus, from $A = \frac{1}{2} bh$, we may evolve—

$$\text{(i) } h = \frac{2A}{b} \text{ and (ii) } b = \frac{2A}{h}$$

which can be easily applied to problems and calculations.

The Right-angled Triangle

The area of a right-angled triangle is a special case worthy of attention.

If any right-angled triangle is examined, it will be noted that the area may be easily found by finding half the product of the two sides containing the right-angle.

Thus (see Fig. 9), if the two sides are a and b, the area is $\frac{1}{2} ab$.

It is, further, true that, if c is the longest side and x the shortest distance from this side to the side c, then the area of the triangle is also $\frac{1}{2} cx$.

But if

$$\frac{1}{2} cx = \frac{1}{2} ab = \text{Area}$$
$$\text{then } cx = ab$$
$$\text{and } x = \frac{ab}{c}$$

which gives a very convenient formula for calculating the shortest distance from the right-angle to the hypotenuse. Thus, applying this formula to the well-known 3, 4, 5 case of the right-angled triangle, we have—

$$a = 3,\ b = 4, \text{ and } c = 5,$$

hence x, the distance from the right-angle to the hypotenuse in such a triangle, is $\frac{12}{5}$ or $2\frac{2}{5}$.

The right-angled triangle is of particular value in dealing with the mensuration and trigonometry of all triangles, for any triangle can be converted at once into two right-angled triangles by the addition of a single line (see Fig. 10).

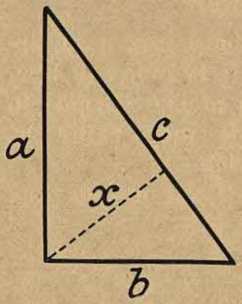


FIG. 9

Area of Right-angled Triangle

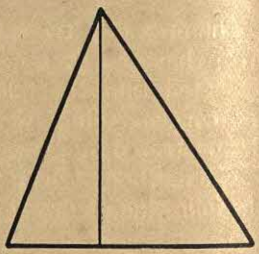


FIG. 10

Triangle Converted into Two Right-angled Triangles

The problem is frequently simplified by dealing separately with each of these two right-angled triangles.

Problems and Calculations Involving Triangles

As soon as the formula is grasped by the pupils, the range of application is unlimited. Problems and exercises may take various forms, such as the following—

1. All-practical problems involving the finding of a triangular area, without having any

data supplied. This area may be small or large, from triangles supplied in paper or cardboard, to triangular areas in garden, playground, or field. Accuracy depends upon the careful measurement of base and altitude, and the larger examples require time and patience before the data can be accurately determined.

2. Examples based upon diagrams and drawings, either supplied by the teacher or made by the pupils. These exercises are similar to (1) except that the work can be confined to the classroom.

3. Examples of the ordinary type, where the dimensions are all supplied, and the calculation alone need be performed. These examples are dull and mechanical, as soon as the principle is grasped, for, as with all mensuration, real interest can only be maintained if the pure arithmetical side is regularly associated with real and practical exercises involving drawing and measurement.

Combinations of Rectangles and Triangles

Numerous common areas can be resolved into triangles and rectangles, and the total area of such figures easily calculated as the sum or difference of one or more rectangles and triangles. In Fig. 11 we indicate a few of these areas.

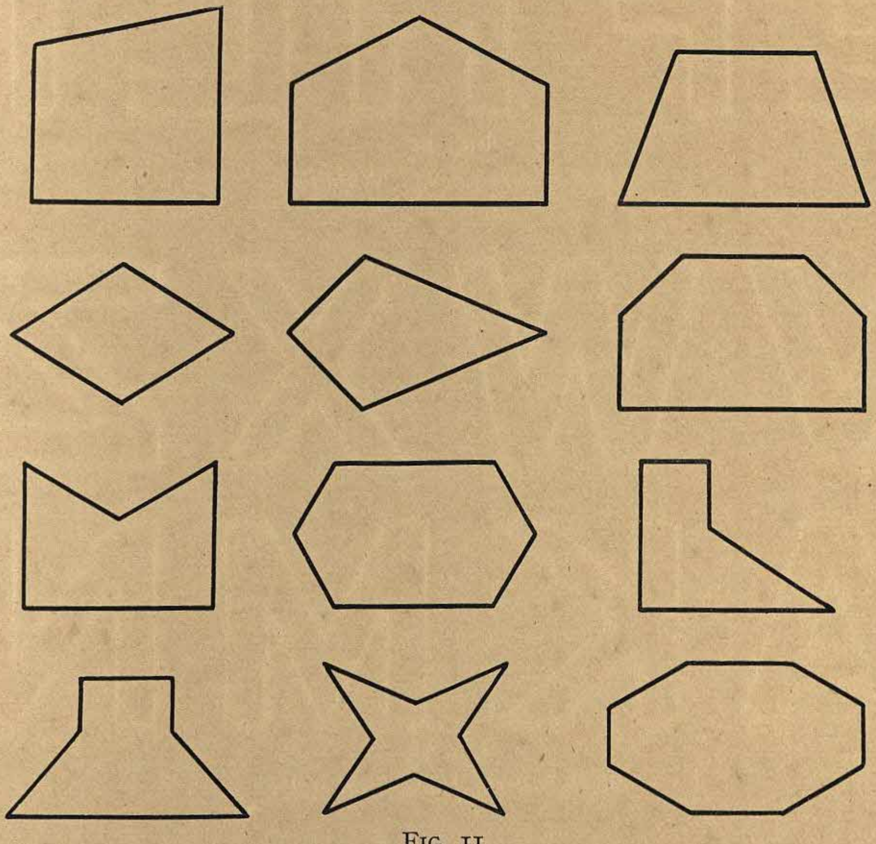


FIG. 11

Combinations of Rectangles and Triangles

If simple dimensions are given to areas of the above kind, the pupil will receive ample practice, in such examples, in the calculation of rectangular and triangular areas.

Block letters, drawn to suitable dimensions, form another useful group. Among them we may note those shown in Fig. 12.

Harder examples, introducing triangular areas, are given in Fig. 13.

If these block letters are given generous dimensions, they provide excellent examples for the calculation of areas, and the simpler cases are popular with examiners for Scholarships and Special Places.

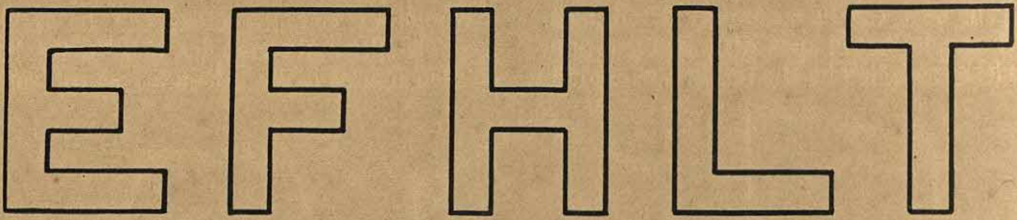


FIG. 12

Block Letters: Area Calculations

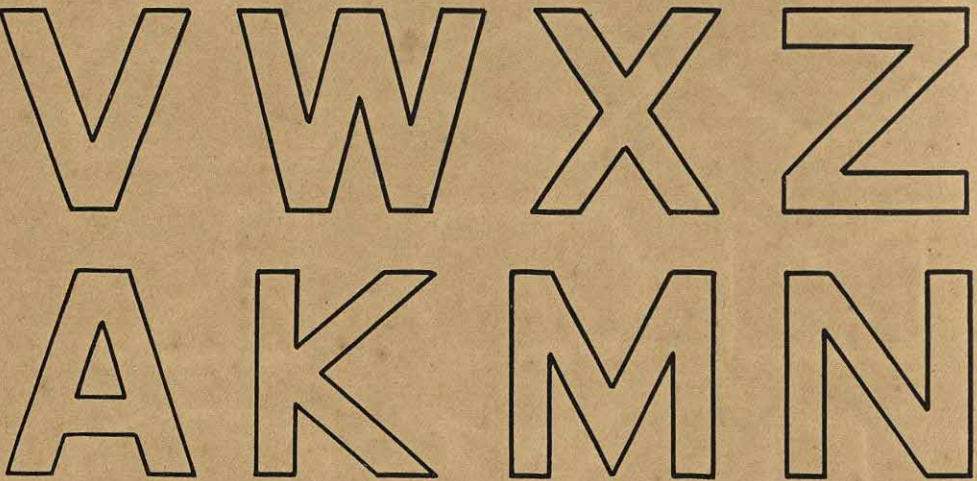


FIG. 13

Block Letters: Harder Examples

The Trapezoid or Trapezium

Following naturally from the areas of rectangles, triangles, and parallelograms, the area of this figure is extremely important. A trapezoid, or trapezium, may be defined as a figure (see Fig. 14) having four sides, two of which are parallel to each other. Any such area may be treated, from first principles, as a combination of rectangles and triangles, as indicated in Fig. 15, but it is convenient at this stage to reduce the finding of the area of a trapezoid to a formula or rule.

The evolution of this rule is readily seen from an examination of Fig. 16, where the original trapezoid is seen to be capable of conversion

FIG. 14

Example of a Trapezoid

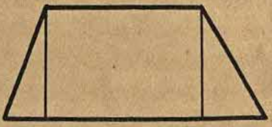


FIG. 15

Trapezoid a Combination of Rectangles and Triangles by means of drawing and paper-cutting into a rectangle whose area is given by the formula—

Area = (Mean length of the Two Parallel sides) × (Distance between the parallels)

which is the usual form in which the formula is memorized.

In arriving at this formula, pupils should carefully demonstrate its truth by exercises in drawing and paper-cutting, such as are illustrated above.

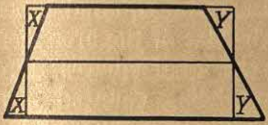


FIG. 16
Trapezoid: Demonstration of Formula

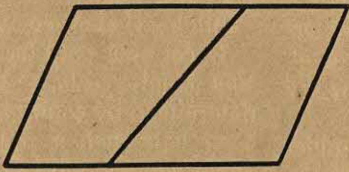


FIG. 17
Trapezoid: Alternative Demonstration

The formula for the area of a trapezoid may also be deduced from the fact that two equal trapezoids may be so arranged (see Fig. 17) as to form a single parallelogram. We leave the deduction of the formula as an exercise for the reader.

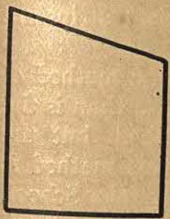


FIG. 18
Right-angled Trapezoid

Of particular importance is the right-angled trapezoid illustrated in Fig. 18. Cases in which areas of this type occur are too numerous to mention, and the area itself is capable of being expressed in a very simple form.

Taking the general formula for a trapezoid as given above, we have—

Area = (Mean length of the two parallel sides) × (Distance between the parallels)

which reduces, in the particular case illustrated by Fig. 18, to—

Area = Base × Mean Height,

and this is a very easy and convenient form for numerical calculation.

We shall indicate later how this same formula for the area of a trapezoid enables extremely simple formulae to be evolved for finding the area of an annulus or circular ring, and the area of the carved surface of the frustum of a cone.

Areas of Irregular Right-lined Figures

Having mastered the methods for finding the areas of Rectangles, Parallelograms, Triangles, and Trapezoids, the pupil is now capable of developing methods for finding the area of any polygon, from quadrilaterals onward.

Any irregular polygon can be divided by lines into a series of triangles, as shown in Fig. 19.

Pupils may accordingly be given practice in finding such areas from first principles, i.e. by dividing them into triangles and then measuring the base and height of each triangle.

In connection with the regular polygons, pupils readily note that the polygon can be divided by means of lines radiating from its centre, and accordingly the area of a regular polygon is expressed easily as a multiple of one of these equal triangles.

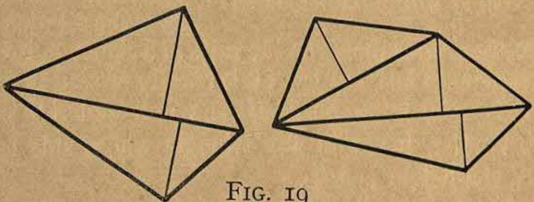


FIG. 19
Irregular Polygons Divided for Calculations

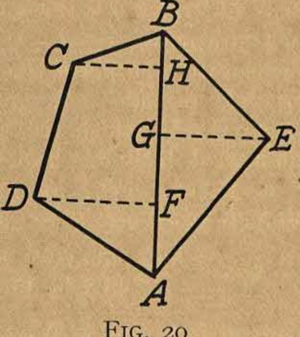


FIG. 20
Measuring Irregular Area

Methods Employed in Field Work

Pupils at some stage of their Senior School mathematical curriculum should be introduced to the ordinary methods of the Field Book, where an irregular area is measured and mapped as indicated in Fig. 20. Here a convenient central line (AB) is chosen, and measured, and the necessary off-sets at right-angles to AB are measured and recorded (e.g. FD, GE, and HC). The area to be determined is thus reduced to convenient triangles and trapezoids.

The Equilateral Triangle

This triangle is of such importance in both Mensuration and Geometry that pupils should be able to determine its area with accuracy and speed.

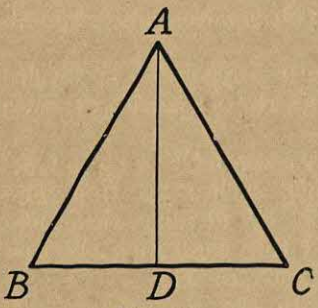


FIG. 21

Area of Equilateral Triangle

In any equilateral triangle the relation between the height and the side is readily determined by the well-known theorem of Pythagoras, which gives the relation between the squares on the sides of a right-angled triangle. Thus, in Fig. 21 it is readily proved that if $AB = 2$ units, then BD is 1 unit and AD is $\sqrt{3}$ units, hence in any triangle whose side is $2s$, the height is $\sqrt{3} \cdot s$.

From this, it follows that the area of an equilateral triangle $\left(\text{i.e. } \frac{\text{base} \times \text{height}}{2}\right)$ is given by $\sqrt{3} \cdot s^2$ where s is half the length of the side, or $\sqrt{\tfrac{3}{4}}a^2$ where a is the length of the side. But $\sqrt{\tfrac{3}{4}}$ is approx. 1·732 ÷ 4, or ·433, hence, for mensuration purposes, the area of an equilateral triangle of side x is given by the formula $A = \cdot 433x^2$, which is easily adaptable to numerical, including logarithmic, calculation.

EXAMPLE. *Find the area of an equilateral triangle whose side is 10 inches.*

$$\begin{aligned}\text{Area} &= \cdot 433\ (10^2) \text{ or } \cdot 433 \times 100\\ &= 43{\cdot}3 \text{ sq. in. approx.}\end{aligned}$$

Irregular Areas Not Bounded by Straight Lines

Areas in actual life unfortunately seldom conform to the precise rules of mensuration and geometry, and accordingly, in so-called "practical mathematics," many interesting methods for approximating to such areas have been evolved. These methods are perhaps beyond the scope of the ordinary Senior School syllabus, but some of them may be conveniently introduced with the oldest and brightest pupils, particularly in Selective Central Schools and ordinary Senior Schools with a very definite technical bias.

Among these we may mention the following—

1. An area may be drawn on squared paper to a definite scale, and the size of the area then determined by counting the small squares, more than half such a square being counted as a whole square, and less than half a square being neglected. The method is interesting, but the results are not very reliable, unless the area is accurately represented to a good scale.

2. An area may be determined by the mid-ordinate rule, the area being first divided into a convenient number of strips, and each strip being assumed to be a trapezoid, whose area, as indicated above, is readily determined by a simple rule. The method gives reasonably accurate results, even for areas bounded by curved or irregular lines, if sufficient strips are taken.

3. In determining such areas the method of "Simpson's Rule" is more accurate than is the Mid-ordinate method just described, but the explanation and application of this method is perhaps unsuited for the ordinary Senior School, and it may accordingly be left until the pupil has entered upon the ordinary Technical School course. The Rule and its method of application will be found in any book of Technical or Practical Mathematics.

These irregular areas and the methods of finding them are sometimes considered to be part of the Science syllabus, but they are discussed here as they may equally well find a place in the syllabus of Mathematics.

The Mensuration of the Circle

Calculations involving circles must occupy a prominent place in every Senior School syllabus. The two formulae in most constant use are—

(i) Circumference
$= \pi \times \text{diameter} = 2\pi \times \text{radius}$
(ii) Area
$= \pi \times (\text{radius})^2 = \frac{\pi\,(\text{diameter})^2}{4}$

Algebraically, these are usually expressed as—

(i) $C = \pi d = 2\pi r$
(ii) $A = \pi r^2 = \frac{\pi d^2}{4}$.

From these we may evolve, by "changing the subject" of each formula—

(iii) $d = \frac{C}{\pi}$ (v) $r = \sqrt{\frac{A}{\pi}}$
(iv) $r = \frac{C}{2\pi}$ (vi) $d = 2\sqrt{\frac{A}{\pi}}$

all of which are of great value in computation.

It is customary for the first formula (and incidentally an approximate value for π) to be determined by practical methods from a series of experimental values.

Thus the pupil finds, by actual measurement, the circumferences of a number of circular objects, and their corresponding diameters. In each case the value of the ratio: Circumference : Diameter, is determined by actual division, and the results are tabulated. Most pupils will, it is feared, not proceed much beyond discovering the fact that this ratio is 3 +, and it will be necessary to tell them that this value (π) is approximately $3\frac{1}{7}$, or $\frac{22}{7}$, or more accurately 3·1416.

As soon, however, as the formula is grasped, arithmetical applications are possible, and pupils may at once be set the task of determining Circumferences, Diameters, or Radii from given data. Wherever possible, calculations should be compared with results obtained by practical experiment. Thus the diameter of a halfpenny is 1 in., and the circumference, therefore, by calculation, should be $3\frac{1}{7}$ in. approx. This actual circumference may be found practically by the simple method of rolling, and the result compared with that obtained from the formula.

The formula for the Area of a Circle is readily proved or deduced by strictly mathematical methods, but for Senior School pupils the formula, $A = \pi r^2$ or $\frac{\pi d^2}{4}$, can be demonstrated but not strictly proved. Several ingenious demonstrations of the truth of this formula are available, the one most commonly used in schools being that in which the circle is first divided into a large number of equal sectors, these sectors being re-arranged to form, in the limit, a rectangle, of which the sides are r and πr, hence the area of this rectangle approximates to πr^2.

The formula may equally well be deduced from a consideration of *one* of these sectors. As the vertical angle of these sectors becomes smaller and smaller, each sector approximates to a triangle whose height approximates to the radius of the circle. Hence the sum of the areas of all the sectors (i.e. the area of the circle itself) becomes, on the triangle formula, $\frac{1}{2}$ (circumference) (radius) or $\frac{1}{2} \cdot 2\pi r \cdot r = \pi r^2$.

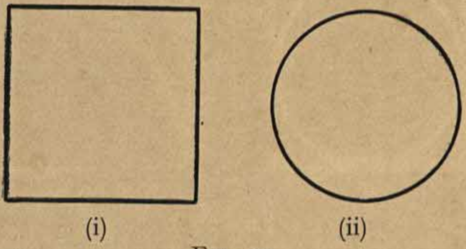


FIG. 22
Mensuration of Circle

Experimental methods for verifying the relation between the area of a circle and the area of its circumscribing square are possible. All that is necessary is that the square and the circle shall be accurately cut from material of uniform thickness. The two figures can then be weighed and compared, and the result compared with that obtained by calculation.

Thus, in Fig. 22, (i) and (ii), the diameter of the circle is of the same length as the side of the square.

Hence Area of square $= d^2$
and Area of circle $= \frac{\pi}{4} \cdot d^2$.

From this we may deduce the simple relation—

Area of Square : Area of Circle :: 4 : π
or 28 : 22
or 14 : 11

This relation should be approximately obtained by the method of weighing indicated above.

Relations of this type are useful for finding solutions of problems of the following kind—

From a square the largest possible circle is cut. What approximate fraction of the original square is left?

This is seen at once to be $\frac{3}{14}$, from the relation given above.

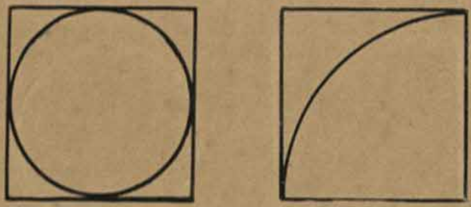

(i) (ii)

FIG. 23
Maximum Circle Cut from Square

Pupils may also discover for themselves the interesting fact that if a circle and a quadrant are each inscribed in a square of the same size, they are equal in area, i.e.—

$$\text{Area of Circle} = \frac{\pi d^2}{4}$$

where d is the side of the square, and, similarly—

$$\text{Area of Quadrant} = \frac{\pi d^2}{4},$$

since it is one quarter of the larger circle of radius d.

Areas of Parts of Circles

Rules for calculating areas of certain parts of circles have been evolved. Among the most important of these parts of circular areas are Sectors and Rings.

Sectors present no difficulty, for, on the same reasoning as that applied to the determination of the area of the whole circle, it may readily be deduced that the area of a sector is given by $\frac{1}{2}$ (Arc of sector) × (Radius).

Particular sectors, such as semicircles and quadrants, may, of course, be deduced by other and simpler methods.

Where the angle of the sector is given, we may at once apply a simple proportionate formula, e.g. If the angle of the sector is $x°$ then the area of the sector is $\frac{x}{360}$ of the area of the whole circle.

The Circular Ring

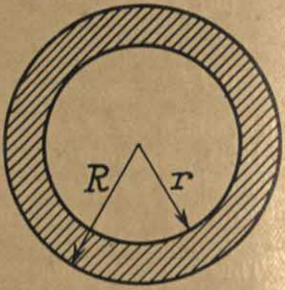


FIG. 24
Area of Circular Ring

In everyday life, circular rings occur as frequently as circles, and it is desirable, therefore, that the pupil should be able readily to calculate the area of a circular ring, such as is seen in the cross-section of a tube, pipe, or hollow cylinder, and illustrated in Fig. 24.

From first principles, the area of a circular ring, whose outer and inner radii are R and r respectively, is clearly the difference in the areas of the two circles, i.e.—

$$\pi (R^2 - r^2) \quad . \quad . \quad . \quad . \quad \text{(i)}$$

This readily transforms algebraically to—

$$\pi (R + r) (R - r) \quad . \quad . \quad . \quad \text{(ii)}$$

But $\frac{R + r}{2}$ is the mean radius of the ring, and $R - r$ is the thickness, hence the formula (ii) may be expressed as

$$2\pi \text{ (Mean radius) (Thickness)} \qquad \text{(iii)}$$

or more simply still, as

(Mean Circumference) (Thickness).

As an example we may give the following—

Find the area of the cross-section of a hollow cylinder, whose outer and inner diameters are 3 *in. and* 2·5 *in. respectively.*

Here the mean diameter is clearly 2·75 in., and the mean circumference accordingly is π (2·75) in. Now the thickness is ·25 in., hence the area of the cross-section is given by

$$\pi \text{ (2·75) (·25) sq. in.}$$

GEOMETRICAL METHOD FOR DETERMINING THE AREA OF A CIRCULAR RING

The following simple and interesting geometrical method is worthy of note—

Consider any circular ring of which the outer and inner radii are R and r respectively. The area of the ring is (as indicated above) $\pi (R^2 - r^2)$.

In Fig. 25, $OA = R$, and $OB = r$, while ABC is the tangent to the smaller circle at B.

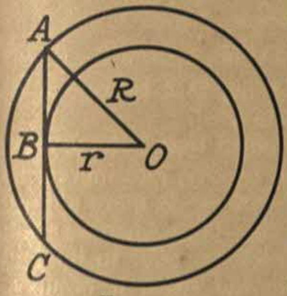


FIG. 25

Area of Circular Ring: Geometrical Method

Clearly

$$\pi (R^2 - r^2)$$
$$= \pi (\overline{OA}^2 - \overline{OB}^2)$$
$$= \pi (AB)^2$$

by the Theorem of Pythagoras (p. 79).

Hence in any circular ring the area may be found geometrically as equal to the square of half any tangent to the inner circle, multiplied by the constant quantity π.

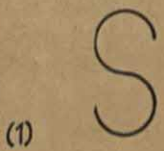
The History of π

The history of the attempts to evaluate this symbol forms a fascinating page in the general history of Mathematics. An excellent account is found in the section entitled "The Quadrature of the Circle" in the well-known volume, *Mathematical Recreations and Essays*, by the late W. W. R. Ball. Here may be read the story of the efforts of circle-squarers through many centuries, but it was not until the eighteenth century that it was definitely established that the quantity known as π was incommensurable, and as such was incapable of finite numerical evaluation. Many approximate values, however, have been propounded, and are in common use. The Egyptians appear to have used the value $(\frac{16}{9})^2$, i.e. $\frac{256}{81}$, or 3·1605. Archimedes demonstrated that the value lay between $3\frac{1}{7}$ and $3\frac{10}{71}$, or between 3·1428 and 3·1408; Ptolemy gave a sexagesimal value of 3° 8′ 30″ or 3·141666, while the Romans appear to have preferred the more approximate $3\frac{1}{8}$. Many other approximate values appear to have been used by the Hindus, Chinese, and Arabs.

We conclude this section with some typical exercises from Pitman's *Common-sense Arithmetic for Senior Boys*, Book III (for pupils age 13–14).

(1) (*a*) Find the total length of the letter S, if each half is composed of three-quarters of a circle of 2-in. radius. (Fig. 1.)

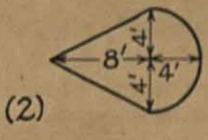
(*b*) Draw this letter half its actual size.



(2) (*a*) Draw the kite (Fig. 2) to the scale of 1 in. = 1 ft.

(*b*) Find the total area of the kite.

(*c*) Find, by measurement and calculation, the total distance round its edge.

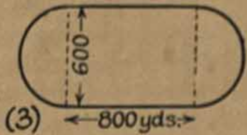


(3) Fig. 3 represents a race-course. The measurements are in yards.

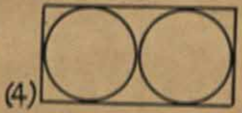
(*a*) Find the total distance round the course.

(*b*) Find the total area within the track.

(*c*) Draw the figure to scale, using 1 in. to represent 100 yd.



(4) Fig. 4 represents a piece of tin which is 2 ft. long and 1 ft. wide. Two circular pieces are cut out of it, as in the figure. Find the area which is left.

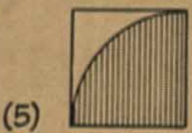


(5) Fig. 5 represents a square of 10 in. side. Find

(*a*) The shaded area.

(*b*) The unshaded area.

(*c*) The length of the curved line.



(6) Fig. 6 represents a design drawn in a square of 6-in. side.

(*a*) Draw the figure full size.

(*b*) Find the total area of the four shaded parts.

(*c*) Find the unshaded area.

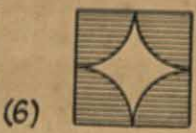


FIG. 26

Circular Measurements

THE MEASUREMENT OF VOLUME

The measurement of Volume has always been included in the ordinary school arithmetical syllabus, and special attention is accordingly devoted to this subject in the syllabus for the Senior School, particularly in regard to the mensuration connected with the more common regular solids, such as rectangular solids, prisms, pyramids, cylinders, cones, and spheres.

The Units of Volume

These present little difficulty. Pupils in the Junior School are now introduced to such things as cubic inches and cubic feet, and should accordingly be familiar with these units and their numerical connection, e.g. 1 cub.ft. = 1728 or (12 × 12 × 12) cub. in. At the Senior Stage, the elements of solid geometry may be begun by the careful examination of a cubic inch in wood. From this, the pupil may note that in every rectilinear solid similar to a cube there are six faces, eight angular points, and twelve edges. Further, he may note that cubes of 2 in. edge, 3 in. edge, 4 in. edge, and so on, have corresponding volumes of 8 cub. in., 27 cub. in., 64 cub. in., etc. Again, in the Handwork or Manual Instruction lesson he may draw the "net" of a cubic inch or of a square prism as a preliminary to constructing these solids in cardboard or sheet metal (see Fig. 27).

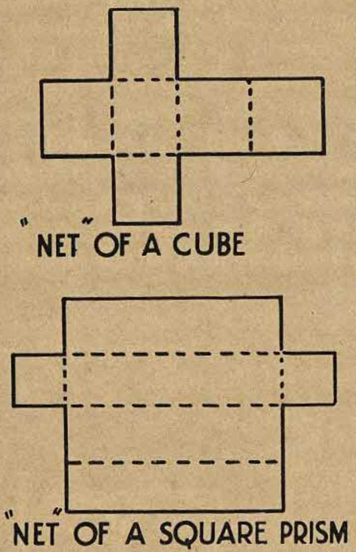


FIG. 27

The Formula for Rectangular Volumes

This formula is readily appreciated if sufficient practical work in the actual manipulation of inch-cubes is given. The fundamental expression is—

Volume = Length × Breadth × Height

or $$V = L.B.H. \quad . \quad . \quad . \quad . \quad \text{(i)}$$

Variations of this formula, according to particular applications are—

$$V = \text{Base area} \times \text{Height} \quad . \quad \text{(ii)}$$

This is valuable in dealing with cylinders, columns, and similar solids.

$$V = \text{Cross-section} \times \text{Length} \quad . \quad \text{(iii)}$$

This is valuable in dealing with timber, metal pipes, and similar volumes.

Further, it may be noted that Volume refers equally to *space* as to *solidity*, and indeed the fundamental idea of Volume is more akin to Capacity than to content. Thus, when we speak of the volume of a brick, we refer to its solid content as well as to the space it occupies, whereas when we speak of the volume of a room, we think rather of the volume of air space it includes.

From the fundamental formula—

$$V = L \times B \times H$$

we may, by changing the subject, obtain three other useful formulæ, viz—

$$L = \frac{V}{B \times H} \quad . \quad . \quad . \quad . \quad \text{(iv)}$$

$$B = \frac{V}{L \times H} \quad . \quad . \quad . \quad . \quad \text{(v)}$$

$$H = \frac{V}{B \times L} \quad . \quad . \quad . \quad . \quad \text{(vi)}$$

As soon as the fundamental principles and formulæ are grasped, the applications available are endless, for rectangular solids abound in ordinary life.

Among these we may mention—

(*a*) Bricks, walls, rooms, houses;
(*b*) Baulks and beams of timber;
(*c*) Boxes of every kind;
(*d*) Tanks and cisterns;

while small objects in the form of rectangular solids are too numerous to mention.

These smaller objects, wooden blocks, bricks, small boxes, etc., should be in constant use for practical work. The older *Handbook of Suggestions for Teachers* contained some excellent advice on this matter, advice which unfortunately is omitted from the later (1927) edition of the *Suggestions*. We therefore make no apology for quoting it in full—

> The study of an object from the geometrical and arithmetical points of view will involve some or all of the following processes—
>
> (i) The measurement of the actual object.
> (ii) Its representation by drawings.
> (iii) The construction of a model.
> (iv) Various calculations involving quantities and costs.
>
> The relative value of these four processes will be found to vary according to the progress of the pupil and the nature of the problem: but the construction of a model is likely to lead to clearer conceptions and to yield more interest than a mere examination of the object. One simple example is given to show what can be done with the very commonest materials—an empty matchbox may afford many exercises of varying degrees of difficulty, viz. observation of the shape of the sides, the number of edges, the number of corners, and the nature of the angles; measurement of the dimensions of the box; drawing the dissected box to scale; construction of a model of half or double the size of the original; calculation of the size of a sheet of cardboard required to make a box; calculation of the size of a parcel containing a gross of boxes, and of the cost, at a given rate, of the cost of the cardboard required to make a gross.

Here indeed are sufficient suggestions to form a most profitable "project" or "quest" for a Senior School pupil or group of pupils.

The Inter-connection of Volume, Capacity, and Weight

The relation of these conceptions of volume, capacity, and weight is particularly important in the case of water, and through water, the pupil may be introduced to the whole subject of relative density. The fundamental numerical relations are soon determined. Thus pupils may find, from actual weighing, that 1 gal. of water weighs approximately 10 lb. Further, they may learn, by actually measuring with convenient receptacles, that a vessel holding 1 cub. ft. of water will also hold approximately $6\frac{1}{4}$ gal.

These relations, viz.—

1 gal. of water = 10 lb. approx. . (i)
1 cub. ft. = $6\frac{1}{4}$ gal. . . (ii)
1 cub. ft. of water = $62\frac{1}{2}$ lb. approx. . (iii)

are of the greatest possible use in numerical calculations. Other facts may be readily deduced. Thus, from (i) we have 1 ton of water = 224 gal., and from (ii) we have 16 cub. ft. = 100 gal., while by combining the two latter facts we may note that 1 ton of water occupies approximately 36 cub. ft., i.e. a tank, 6 ft. × 6 ft. × 1 ft., would hold approximately 1 ton of water.

It is essential that at the outset the pupils should not accept these relations merely on the authority of the teacher. Thus, at some period of his arithmetical curriculum, a pupil should have the pleasure of attempting to determine *for himself* with fair accuracy the weight of a pint or of a gallon of water.

Again, the connection of volume with rainfall and the rain-gauge is important. Pupils should have a clear idea of the meaning of a rainfall of 1 in., and should be able to calculate that such a rainfall is approximately 101 tons of water per acre.

The calculation is here given—

$$\begin{aligned}\text{Volume of water} &= 1\text{ in.} \times 1\text{ acre}\\ &= (\tfrac{1}{12} \times 4{,}840 \times 9)\text{ cub. ft.}\\ &= 3{,}630\text{ cub. ft.}\\ \text{Weight} &= (3{,}630 \times 62\tfrac{1}{2})\text{ lb.}\\ &= \left(\frac{3630 \times 125}{2240 \times 2}\right)\text{ tons}\\ &= \left(\frac{45375}{448}\right)\text{ tons}\\ &= 101\text{ tons approx.}\end{aligned}$$

If 62·4 lb. be taken as the weight of a cub. ft. of water, the weight per acre is approximately 100 tons.

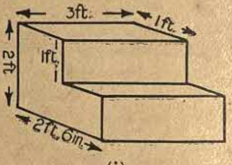
Again, the weight of a cub. ft. of ice is important. If this be taken as approximately 56 lb. (or half a hundredweight) per cub. ft., this provides a ready means of calculating the weight of ice on a pond. Thus if the ice is 2 in. thick on a pool of 10 acres of water, the volume of the ice is

$$\begin{aligned}&(\tfrac{1}{6} \times 48{,}400 \times 9)\text{ cub. ft.}\\ &= 72{,}600\text{ cub. ft.}\\ \text{Weight} &= 36{,}300\text{ cwt.}\\ &= 1{,}815\text{ tons.}\end{aligned}$$

Use of Models and Diagrams of Solid Objects

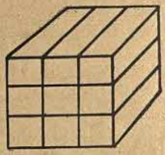
As in the case of rectangular area, models and diagrams are of the greatest assistance to the teacher in setting suitable exercises in volume. As an instance we give a typical exercise taken from *Common Sense Arithmetic for Senior Boys*, Book II (ages 12–13 years)—

(1) (*a*) Find the volume of the stone steps shown in Fig. (i).
  (*b*) Find the total area painted, if all the faces are painted, except the back and base.
  (*c*) If the top step was taken away, what volume of stone would be left?

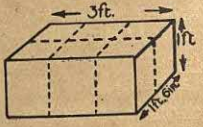


(i)

(2) Nine blocks of wood, each 12 in. long, are arranged as in Fig. (ii), to form a perfect cube.
  (*a*) What is the width and thickness of each block?
  (*b*) If all the faces of the cube are painted red, how many of the blocks will have four faces each painted red?
  (*c*) If the blocks were laid side by side in a single layer, what area would they cover?

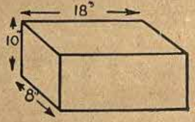

(ii)

(3) Fig. (iii) represents a box whose outside measurements are as shown—
  (*a*) Find its volume.
  (*b*) The dotted lines show cord passing right round the box. Find the total length of this cord, allowing 2 ft. for tying.
  (*c*) Find the total length of all the edges of this box.



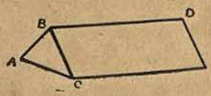
(iii)

(4) Fig. (iv) shows a wooden block—
  (*a*) Find the total area of its six faces.
  (*b*) Find its weight, if 1 cub. ft. weighs 54 lb.
  (*c*) What is the size of the largest cube which could be cut from this block?



(iv)

(5) Fig. (v) shows a prism, whose end ABC is a triangle, having $AB = BC$, and a right angle ABC.
  (*a*) If AB and BC are each 4 in. long, and BD is 10 in. long, find the volume of the prism.
  (*b*) Show how two of these prisms could be arranged to form a rectangular block, and give the measurements of the block.
  (*c*) Show how *four* of these prisms could be arranged to form a rectangular block.



(v)

FIG. 28

Typical Examples in Volume

Prisms and Pyramids

The transition from rectangular solids to other regular solids, such as prisms and pyramids, is natural and easy, and, accordingly, these solids are generally included in a Mensuration Course arranged for Senior Schools.

The work has the additional advantage of combining excellent drawing practice with ruler, set-square, and compasses, where these solids are constructed as models in paper or cardboard, or even in wood or metal.

Rectilinear prisms (of which the ordinary rectangular solid is a particular example), from the triangular prism upward, may readily be constructed if their "nets" are first carefully drawn. We illustrate by two well-known examples—

THE TRIANGULAR PRISM—"NET"

The "net" shown below indicates the whole surface area of a prism. Pupils may be required to draw the "nets" of various triangular prisms, e.g. those having as cross-sections an equilateral triangle; a right-angled triangle; an isosceles triangle; and a scalene triangle. Further, if sufficient "flaps" are left for "gumming" or fastening, these triangular prisms may readily be modelled in cardboard.

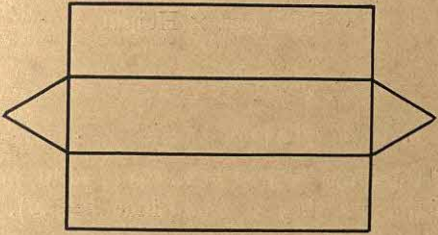


FIG. 29
"Net" of Triangular Prism

THE HEXAGONAL PRISM—"NET"

In order to calculate the volume of such prisms the most convenient formula is—

$$V = \text{Base area} \times \text{Height}$$
$$(\textit{or}\ \text{Cross-section} \times \text{Length})$$

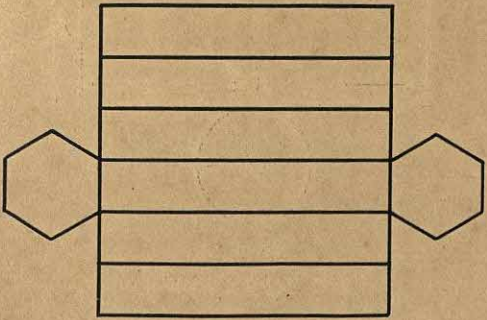


FIG. 30
"Net" of Hexagonal Prism

A very common prism is that afforded by the volume of such an object as a lean-to shed or greenhouse (see Fig. 31), where the end-area or cross-section (X) is in the form of a trapezium. The volume of such a solid is clearly given by Area (X) × Length (L).

This, in practice, reduces to the simple calculation of Length × Width (W) × Mean (or average) height. Similarly, for such a solid as the volume of an ordinary swimming-bath, we have—

$$\text{Volume} = \text{Length} \times \text{Width} \times \text{Average Depth.}$$

Numerical examples based on common objects which embody the above should be set, to fix the formula.

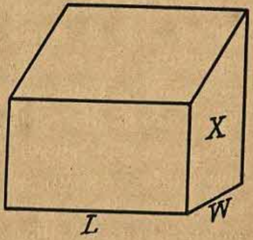


FIG. 31
Lean-to Shed as Prism

PYRAMIDS

These may be dealt with by the same methods as prisms. Thus simple models may be constructed from careful drawings previously made. We give two "nets" to illustrate the possibilities of this constructional work.

(i) "Net" of a regular square pyramid (Fig. 32).

The total surface area of such a prism is of course the area of the "net."

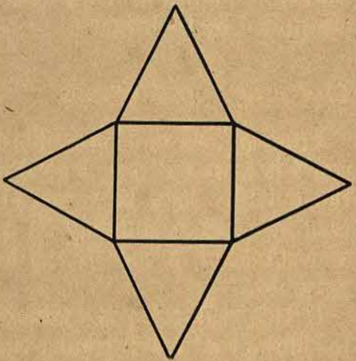


FIG. 32
"Net" of Triangular Square Pyramid

(ii) Net of a regular triangular pyramid (Tetrahedron) (Fig. 33).

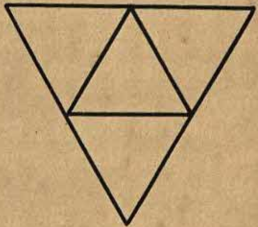


FIG. 33
"Net" of Regular Triangular Pyramid

VOLUMES OF PYRAMIDS

Volumes of pyramids are readily found from the simple formula

$$V = \tfrac{1}{3}\,(\text{Base area} \times \text{Height of pyramid})$$

or, in words: The volume of a pyramid is one-third of the volume of the corresponding prism having the same base area and height.

Proof of this simple formula is difficult for Senior School pupils, though demonstration, especially in certain particular cases, is not impossible. Thus a triangular prism of wood may with care be dissected into three equal pyramids, i.e. pyramids whose weights are approximately the same. Again, as in the case of cones and cylinders, it may be shown that a hollow pyramid can be filled approximately three times with the contents of a hollow prism of the same base and height. Finally, it may be demonstrated by means of a hollow cube that the four long diagonals divide the cube into six equal pyramids. Hence, if the side of the cube is s, it follows that the volume of one of these six equal pyramids is $\frac{1}{6}s^3$, or $\frac{1}{3}(a^2)\left(\frac{a}{2}\right)$, which, in words, is one-third of the base of the pyramid multiplied by its height.

Cylinders and Cones

From prisms and pyramids to cylinders and cones is a step at once logical and simple, since the cylinder may be regarded as the limiting case of a prism standing on a polygonal base, and similarly, a cone is the limiting case of a pyramid.

If this deduction is mathematically correct, it follows that for a cylinder the volume is given by the formula: $V =$ Base area $\times$ Height, and for the cone, $V = \frac{1}{3}$ (Base area $\times$ Height).

"NET" OF A CYLINDER

For constructional purposes, the "net" of a cylinder is easily drawn. It consists, as in Fig. 34, of two circular areas attached to a rectangular area.

The two circles represent the end-areas, and the rectangular represents the curved surface of the cylinder.

The length of the rectangle is clearly the circumference of one of the end-areas, i.e. πd, and the width of the rectangle is the height of the cylinder.

Hence we have the following useful expressions—

Curved surface of a cylinder $= \pi dh$. (i)

Total surface of a cylinder $= \pi dh + \frac{\pi}{2}d^2$ (ii)

or $\pi d\left(h + \frac{d}{2}\right)$

For the volume of a cylinder, we have, on the analogy of the prism—

$$V = \text{Base area} \times \text{Height}$$

$$= \frac{\pi}{4}d^2 \times h$$

$$= \cdot 7854 d^2 h \quad . \quad . \quad . \quad . \quad \text{(iii)}$$

If these are desired in terms of radii, instead of diameters, they become (since $d = 2r$).

Curved surface $= 2\pi rh$ . . . (iv)

Total surface $= 2\pi r\,(h + r)$ . . (v)

Volume $= \pi r^2 h$ . . . (vi)

In actual work it is usually found more practicable to measure diameters than radii, hence, formulæ (i), (ii), and (iii) are more usually applied.

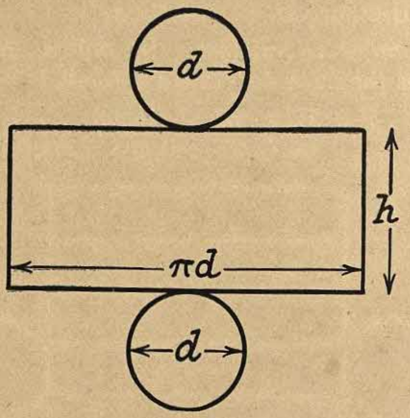


FIG. 34

"Net" of a Cylinder

Innumerable examples occur in ordinary life which provide opportunities for cylindrical measurements and calculations. Cylindrical jars, tins, pipes, columns, and tubes of every variety exist and should form the basis of all practical examples. Thus the pupil may find, from first principles, the volume of a tin or jar; he may determine the volume per foot run of tubing or piping; and he may determine by measurement and calculation the relation between a gallon and a cubic foot, by first finding the internal volume of a two-gallon jar.

In geography, the cylindrical rain-gauge forms an admirable example for investigating the geometry and mensuration of the cylinder, especially if the pupil is set the interesting and more difficult exercise of calibrating the accompanying measuring cylinder. From this he will learn that what is termed an "inch" of rainfall may, by means of a cylinder of smaller diameter, be magnified to much more than 1 in., thereby enabling the actual depth of rainfall to be determined with considerable accuracy.

THE CONE

Development of a Cone

Fig. 35 *a* represents the "net" of an ordinary cone.

This "net" (Fig. 35 *a*) consists of a circle and a sector. The circle represents the base of the cone, and the sector represents its curved surface. An inspection of the cone in Fig. 35 *b* will show that the area of the base is πr^2 or $\frac{\pi d^2}{4}$. The area of the sector is best determined by the formula $A = \frac{1}{2} \times$ circular arc $\times$ radius of the sector. Now the circular arc is equal to the circumference of the base, i.e. to πd or $2\pi r$, and the radius of the sector is equal to the slant height of the cone, hence the curved surface of the cone is given by $\frac{1}{2}(2\pi r) \times l$, where l is the slant height.

Thus, for the cone, we have—

$$\text{Curved surface} = \pi r l \quad . \quad . \quad . \quad \text{(i)}$$

$$\text{and Total surface} = \pi r^2 + \pi r l$$

$$\text{or} \quad \pi r(r + l) \quad . \quad . \quad \text{(ii)}$$

The Volume of a Cone

We have already indicated that the volume of a cone, on the analogy of that of a pyramid, is equal to one-third of the volume of the corresponding cylinder having the same base and height, i.e.

$$\text{Volume} = \tfrac{1}{3} \cdot \pi r^2 \cdot h$$

where r is the radius of the base of the cylinder and h is its height.

Mathematical proof of this formula is difficult at this stage, but, in the words of the *Handbook of Suggestions for Teachers*—

> The relation between the volume of a cone and that of a cylinder having the same base and the same height may be verified by using a cone which fits accurately into a cylinder. The contents of the empty cylinder may be ascertained by means of a graduated measuring jar, and compared with its contents after the insertion of the cone. Or the weight of sand which the cylinder will hold before and after the insertion of the cone may be compared, or, again, the volumes of water which solid cones or cylinders will displace may be compared, or the weights of accurately made cones and cylinders of the same metal may be compared.

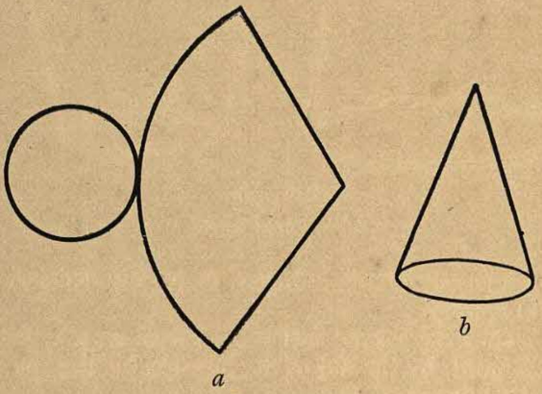


FIG. 35
A Cone and Its "Net"

This extract indicates how, by experiment and demonstration, the relation between the volumes of cones and corresponding cylinders may be investigated, and shows clearly how mathematical truths may be verified and fixed in the minds of pupils by the simple methods of the science- or handicraft-room.

Frustums of Cones

Truncated cones may readily be investigated, particularly with the brighter or "A" section of older pupils in a Senior School. These solid forms, again, figure very largely in ordinary everyday life. Pails, buckets, flower-pots, cans, funnels, and countless other common objects and utensils depend fundamentally for their shape on some form of truncated cone, as illustrated in Fig. 36.

From first principles, it will be noted that a truncated cone or frustum is simply the difference of two complete cones, i.e. a larger cone from which a smaller cone has been cut away (see Fig. 36).

It follows, then, that both the surface and the volume of a frustum can readily be determined by finding the surfaces and the volumes of the larger and smaller cones and then subtracting the results.

Separate formulæ for the surface and volume of a frustum may, however, be readily deduced if required.

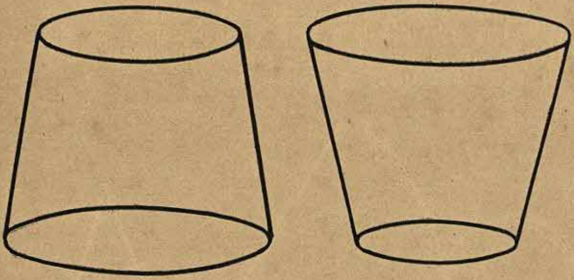


FIG. 36
Truncated Cone

Thus the curved surface of a frustum may be deduced, by the aid of the formula for the area of a trapezium, as

Mean circumference × Slant height

while a slightly longer transformation will indicate that the volume of a frustum is given by—

$$V = \tfrac{1}{3}h\,(S + \sqrt{Ss} + s)$$

where h is the height of the frustum and S and s are the areas of its circular ends.

The Mensuration of the Sphere

Simple formulæ exist for determining the surface and volume of a sphere.

Thus for surface we have—

$$S = 4\pi r^2 \quad . \quad . \quad . \quad . \quad \text{(i)}$$
$$\text{or } \pi d^2$$

which may readily be memorized as being equal to four times the area of a circle of radius r (where r is the radius of the sphere), or as equal to π times the square on the diameter of the sphere.

For volume, we have—

$$V = \tfrac{4}{3}\pi r^3 \quad . \quad . \quad . \quad . \quad \text{(ii)}$$

As in the case of the formulæ for dealing with cones and frustums, mathematical proof of these formulæ for the sphere is difficult at this stage, but they are particularly capable of being demonstrated by practical methods, especially in their relation to the surface and volume of corresponding cylinders.

This relation may be expressed as follows—

(i) SURFACE OF THE SPHERE

This is equal to the curved surface of the circumscribing cylinder (see Fig. 37 below).

Now if r is the radius of the sphere, then r is the radius, and $2r$ is the height, of the circumscribing cylinder.

The curved surface of cylinder is given by circumference × height, i.e. by $2\pi r \times 2r$, or $4\pi r^2$ hence the surface of the sphere is also $4\pi r^2$, as already stated.

(ii) VOLUME OF THE SPHERE

This may be expressed as equal to two-thirds of the volume of the circumscribing cylinder. Now the volume of this cylinder is given by base area × height, i.e. by $\pi r^2 \times 2r$, or $2\pi r^3$, hence the volume of the sphere is given by—

$$\tfrac{2}{3} \times 2\pi r^3, \text{ or } \tfrac{4}{3}\pi r^3$$

This relation is capable of practical demonstration, as in the case of cones and corresponding cylinders.

It follows, of course, that the curved surface of a hemisphere is $2\pi r^2$, and the volume of a hemisphere is $\tfrac{2}{3}\pi r^3$.

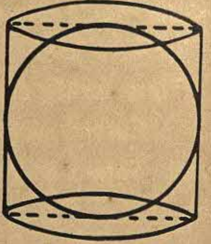


FIG. 37
Mensuration of the sphere

We have now outlined the main lines of the possible development of mensuration in the Senior School. Much of what has been indicated is suitable alike for boys and for girls, and enough has been given to enable a teacher to make a selection of topics or syllabus in mensuration suitable for any ordinary Senior School, department or class.

We shall next discuss in detail the possibilities of geometry in the Senior School.

GEOMETRY IN THE SENIOR SCHOOL

In dealing with mensuration we have already indicated that the arithmetical side of mensuration cannot be dissociated from the geometrical side, and that simultaneously with numerical calculations there must proceed constant exercises in geometry, especially practical and constructive geometry.

This more mathematical view of the interrelation of arithmetic, mensuration, and geometry is supported by the advice given in the *Handbook of Suggestions*, and accordingly we shall quote from this particular section as we proceed to develop our argument.

In the first place it is necessary to try to determine how far our treatment of geometry in Senior Schools shall be practical and experimental, and how far it shall be more formal, logical, rigid, and deductive. It is now universally admitted that, for the average pupil of Senior School age, the best introduction to geometry is through practical drawing, including drawing to scale.

> Scale-drawing, easy ruler and compasses constructions, and the drawing of simple plans and elevations, are matters which will naturally arise in connection with mensuration, handwork, and geography, and can conveniently be carried on concurrently with them. It is probable that these types of drawing, which at one time may have been overdone, are now unduly neglected. Apart from the training they give in themselves, they are of value in leading up to a more reasoned kind of geometry and form a useful groundwork for boys proceeding to a Handicraft Centre. Simple scale-drawing may begin early in the junior classes in connection with handwork or the construction of plans of rooms and playgrounds, and will at first involve the use of the ruler alone. Set-squares and compasses will be used later for more accurate work and more difficult scales and easy ruler-and-compass constructions will be introduced. Thus, by the time the pupil is about 12 years old he should be able to use instruments correctly: to construct with their use angles, perpendiculars, parallels: to construct simple plane figures (e.g. rectangle, triangle, circle, the easier regular polygons) and to draw easy figures to scale. This work may be developed further to some extent later, e.g. to include further constructions such as the bisection of lines and angles. (*Suggestions*.)

Older teachers will recognize in the above paragraph much of the matter formerly included under the heading of a separate subject known as Practical Plane Geometry. Important points to note are the emphasis laid in this extract upon the importance of teaching—

1. The correct use of the ordinary drawing instruments.

2. The more elementary aspects of scale drawing.

It is interesting to note, too, that work of this kind is considered to be of equal importance both for boys and for girls. Thus, in that section of the most recent *Handbook of Suggestions* which deals more particularly with mathematics in Senior Schools for Girls, we read the following—

> Geometry, together with drawing to scale and mensuration, should be an important part of the training. Commonly these topics are relatively neglected in Girls' Schools, or if geometry is taken, it is sometimes of too theoretical a kind and omits altogether such interesting applications as finding heights and distances by practical measurement. The fact that the girls miss the scale-drawing and plan-and-elevation work of the handicraft course should be a reason not for doing less but for doing more in mathematics. (*Suggestions*.)

Scale-Drawing

This should be made as real as possible. Pupils should be required to work from freehand sketches or diagrams supplied, and to select for themselves the most convenient scale to be used in any given case. The older method of working from formal copies, where the scale to be used was indicated, is to be discouraged. This sensible selection of scales by the pupil is extremely important (as we shall note later) in the drawing of graphs on rectangular axes, for clearly, where an unsuitable scale is selected for either axis, the graph which results will be too small, or too large, or unnecessarily distorted. Scale-drawing should, of course, be as *real* as possible, i.e. it should be associated where possible with actual problems, projects, and quests. Mere purposeless drawing will soon lose its attraction, even for the most enthusiastic pupils.

Plans and Elevations

It is now recognized that exercises of the plan-and-elevation type should appear in every Senior School syllabus. We have already indicated repeatedly the use which may be made of actual plans, particularly if these are drawn to scale by the pupils themselves, and it is now advocated that the work may be gradually extended, so as to include finally much of the work which formerly appeared as "Solid Geometry."

The work may be begun quite early in the Senior School course, i.e. about the age of twelve—

> At this age, ideas of plans and elevations which will have arisen in connection with geography, model-drawing, and mensuration, can usefully be extended and made more definite by developing them in connection with handwork. As a necessary preliminary to the drawing of a plan and elevation, the pupil may be taught to make a simple hand sketch from his own measurements. By the time a child leaves school there is no reason why he should not be able to draw plans and elevations of simple solids in easy positions and to draw some of their easier sections, such as are needed in Handicraft Centres. (*Suggestions.*)

Simple Constructions

We have already indicated that the use of instruments, such as ruler, set-square, compasses, and protractor, must be taught and practised, and this essentially practical side of geometry must appear prominently in any syllabus. Unfortunately the subject suffered in the past by being taught merely as a collection of bookish tricks to be memorized, and having apparently no actual applications. With the development of handicrafts and design of every description in our schools to-day, the subject of practical drawing has attained a new importance, though the criticism mentioned above has occasioned the following warning in the *Suggestions*—

> Wherever possible the work in geometry attempted in the Elementary School should be given a practical application. Constructions of an academic and sometimes complicated nature, such as inscribing three circles in a triangle to touch one another, were formerly common in Elementary Schools. They are of little value from the geometrical point of view, since they cannot be done without detailed instructions, the reasons for which are seldom understood by the pupils. Their chief merit was the practice they afforded in the accurate use of drawing instruments, a power to which great importance should still be attached. Equally good practice, however, can be obtained in work which has a definite purpose; thus, the construction of a simple geometrical design for the decoration of some piece of handwork undertaken by the pupil may afford an excellent exercise in the use of ruler and compasses. Many good examples of geometrical construction arise in the setting out of the handwork in cardboard and wood. For instance, it is often necessary to bisect an angle, to find the centre of a circular arc, or to construct a figure such as a regular octagon; it is therefore important that the work in geometry should be suitably co-ordinated.

Formal Geometry in the Senior School

It is generally agreed that a place should be found in the syllabus for some orderly development of the more formal aspect of geometry. It is also admitted that to attempt to teach the subject solely by means of the older type of deductive Euclidean geometry is wrong.

This aspect of the whole subject is well expressed in the Hadow *Report on the Education of the Adolescent*, where we read—

> Geometry may be suitably introduced when the pupil is dealing with the areas of rectangles, squares, and triangles. In general there will be little formal deductive work, save from experiments, and the course in general will follow the lines of experimental geometry, such as is now to be found in good modern textbooks. It should not be confined to two-dimensional work. Practical work in the mensuration of solids will necessitate a certain amount of three-dimensional geometry of a simple character. It will be closely associated on the one hand with the work in mensuration and arithmetic, and on the other, through geometrical drawing, with manual training. It should not, however, develop merely in a series of mechanical exercises in geometrical drawing. Such work has its usefulness, but it is more important that geometry should be utilized, as far as is possible, within the limits imposed by circumstances, as a means of training in deductive processes and logical thinking.

The same point of view is elaborated in the *Handbook of Suggestions for Teachers* as follows—

> It is clear that formal geometry, i.e. the sequence of definitions, postulates and propositions of Euclid or recent alternative sequences, is unsuitable for a child's first reading of the subject, and will, therefore, not find its way into the ordinary Elementary School. Such knowledge of the more important geometrical facts contained in the first six books of Euclid as is desirable at this stage may best be obtained through practical work, and almost from the first this work can be made to serve a fuller purpose, if the teacher bears in mind that the items of geometrical information bear a relation to one another and are not simply useful and interesting in themselves. Further, the

> making of accurate drawings may lead to the discovery of geometrical relations of general application.
>
> The possibilities which the subject affords for training in reasoning and in logical statement should be borne in mind. In the early stages there will be no attempt at a memorized proof, but the pupil should be trained to state the steps of an argument in concise, if informal, language. Formal definitions are out of place, but precision should be given to ideas by teaching the correct use of a few technical terms.

From the above extracts it will be seen that the course, while essentially practical, shall be orderly and logical. Little is heard, in these extracts, of the heuristic methods formerly so popular, but the method of discovery remains as useful to-day as ever, and the pupil should never be *told* a fact which he can discover for himself in a reasonable time through the ordinary experimental methods. Again, the general view is hardly sufficiently definite on the question of direct or indirect treatment. While much geometrical theory may be learnt by incidental methods in handwork and other lessons, we think, on the whole, that the balance of opinion is in favour of a more definite and consecutive treatment of the subject, at least in the higher classes of the school. Accordingly, it is desirable that the work in geometry in the Senior School should be arranged in some orderly sequence or syllabus. The truths to be investigated will follow in the main the order of the Euclidean development, and careful selection by the teacher is essential. Here the *Handbook of Suggestions* is very definitely helpful, for we read—

> The following topics are suggested as covering the main body of material from which selection may be made. The order is not intended to indicate the order of study or the order of importance; this will depend largely upon the method of treatment.
>
> (*a*) Lines, angles, and parallels.
>
> (*b*) Simple geometrical forms and constructions and scale drawing.
>
> (*c*) The angle property of a triangle and its extension to other figures.
>
> (*d*) Symmetry and similarity.
>
> (*e*) Measurement of area and volume.
>
> (*f*) Theorem of Pythagoras.
>
> (*g*) Angle properties of circles.
>
> (*h*) Simple solids. Plans and elevations.
>
> Schemes of work will probably vary more in the extent to which each of these topics is developed than in the number attempted. For example, topics (*a*) and (*b*) will arise naturally in any course of work with rulers, protractors, and compasses and will therefore be dealt with, in simple form, in all schools.

We have already discussed some of these topics incidentally, and shall now proceed to discuss in more detail certain of their geometrical aspects.

PRACTICAL GEOMETRY

I. Lines, Angles, and Parallels

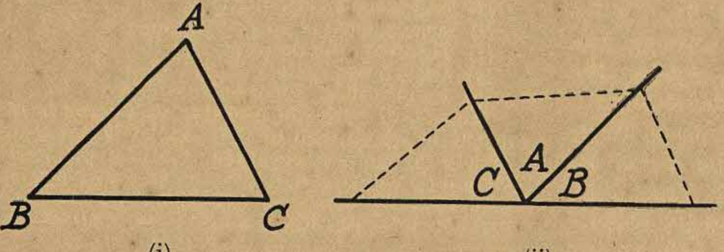
All the ordinary truths may be discovered experimentally by exercises in drawing and measurement. Pupils must of course be able to draw lines, angles, and parallels by the usually accepted methods. Thus they must know how to draw a line making a given angle with another line; to draw a line at right angles to another line; to find the shortest distance from a point to a line; to draw parallels at given distances apart; and indeed to perform readily any ordinary drawing exercise involving lines, angles, and parallels. Among the important truths which they should discover are the facts: that where one line meets another line the adjacent angles are equal to two right angles; that vertically opposite angles are equal; that parallel lines have peculiar angle properties, such as equal alternate angles, equal exterior and interior angles, and that the sum of two interior angles on the same side of a transverse is equal to two right angles.

II. Simple Geometrical Forms and Constructions and Scale-Drawing

Among constructions, we must teach the drawing of perpendiculars, the copying of angles, and the bisection of lines and angles. All these are necessary in the accurate drawing of rectilineal figures. Among such figures we may mention in particular the regular polygons—the equilateral triangle, the square, the regular pentagon, the regular hexagon, and the regular octagon. Methods for constructing these should be well known by the pupils, since they are of frequent occurrence in handwork and design.

The triangle may be explored fully, and the methods of constructing triangles from given data should be taught. Further, in connection with mensuration and handwork, much practice may be found in the construction of such figures as rhombuses, trapeziums, and other polygons of common occurrence. Finally, the pupil should have practice in reproducing figures or in copying figures to any given scale, e.g. full-size, half-size, etc.

Scale-drawing has already been fully commented upon, and it will suffice here to repeat that it is equally important for both boys and girls, and should be associated with geography and handwork wherever possible.



(i)

(ii)

FIG. 1

Angle Property of a Triangle: Demonstrated by Drawing

III. *The Angle Property of a Triangle and its Extension to other Figures*

The fundamental relation to be grasped here is that the three angles of a triangle are together equal to two right angles.

This truth may be readily discovered through the ordinary means of drawing, measurement, and paper-folding or paper-cutting. Formal proof at this stage is unnecessary. Thus the pupil may proceed inductively by drawing a number of triangles, measuring their angles, finding the sum in each case, and noting that the sum is approximately 180°, or two right angles, for each triangle. Again, he may draw any triangle (preferably fairly large) as in Fig. 1 (i), and then cut off each of the angles *A*, *B*, and *C* and rearrange these along a line to make two right angles as in Fig. 1 (ii).

Or, if paper-folding is preferred, Fig. 2 indicates a simple and easy method of demonstration.

Any triangle *DEF* is drawn. The sides *DE* and *DF* are bisected and dotted lines drawn as shown. The angles are then folded along these dotted lines to meet in a point as shown. It will thus be apparent that the three angles form two right angles.

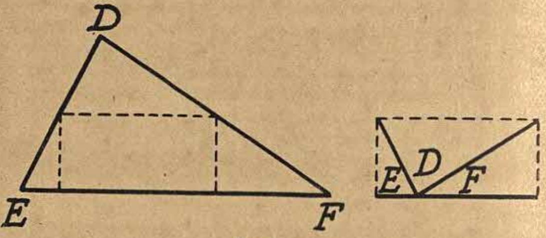


FIG. 2

Demonstration by Paper Cutting

As soon as the fundamental fact is grasped, it is necessary to "fix" the knowledge by means of numerical examples and drawing exercises. We indicate a few of these—

1. Two angles of a triangle are 60° and 70°. What is the third angle?
2. A right-angled triangle has one angle of 40°. What is the third angle?
3. The angle at the apex of an isosceles triangle is 40°. What is the size of each base angle?
4. What is the size of each base angle in a right-angled isosceles triangle?

Examples of the above type may be associated with drawing exercises.

From the triangle we pass to the quadrilateral and all other polygons. Here the important truth is that all the interior angles of a polygon, together with four right angles, are equal to twice as many right angles as the polygon has sides.

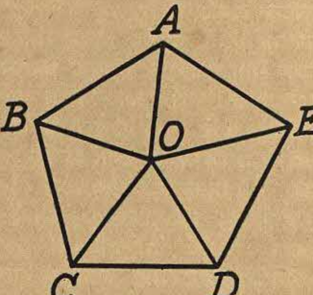


FIG. 3

Interior Angles of a Polygon

This is of course readily demonstrable by the division of the polygon of n sides into n triangles (by the simple process of joining each angular point to a point within the polygon).

Fig. 3 illustrates this for an irregular pentagon. Here we have five triangles, the sum of whose angles is clearly ten right angles. But the sum of the angles at O is 4 right angles. Hence the theorem is true for this figure.

Numerical applications of this fact should be based upon the regular polygons, and many interesting deductions may be made. As soon as the truth is thoroughly grasped, it may, by the simplest algebra, be reduced to formula.

Thus for a regular polygon of n sides, where A is an interior angle of the polygon, we have—

$$n \, . \, A + 4 = 2n \text{ (right angles)},$$

or, in degrees—

$$n \, . \, A + 360 = 180n$$

$$\text{Hence } A \text{ (in degrees)} = \frac{180n - 360}{n}$$

$$\text{or } 180 - \frac{360}{n}$$

Pupils may explore this for all values of n from 3 onward: The algebraic exercise is useful and interesting—

Value of n	Polygon	Angle A
3	Equilateral Triangle	60°
4	Square	90°
5	Pentagon	108°
6	Hexagon	120°
8	Octagon	135°
etc., etc.		

IV. *Symmetry and Similarity*

Symmetry and Similarity are mathematical topics of such fundamental importance and beauty that they should find a place in the syllabus of every Senior School. Though the subject is primarily a geometrical one, it is readily adaptable to numerical calculations, particularly those which involve the principles of proportion and variation. We shall accordingly explore the possibilities of this branch of the syllabus at some length.

The *Handbook of Suggestions* does not deal at any great length with the subject, but the following references should be noted therein—

> (*a*) A good illustration of proportion can be obtained by comparing the lengths of the shadows thrown by two upright rods. The teacher may begin by making the pupils ascertain that the shadow of a 6 ft. rod is twice as long as that of a 3 ft. rod, three times as long as that of a 2 ft. rod, and so on, and he may lead them to infer that in a general way we can obtain a comparison of the two heights from a comparison of the two shadows. Possibly he may sum up the results of his teaching by saying that the length of the shadow is proportional to the height of the post, but he will not attempt to say what proportion is or what it is not. As in other cases the definition can convey no real meaning until the child's mind has become saturated with many examples of the thing or idea defined.
>
> (*b*) Perhaps the most useful of all applications of geometry are those which depend on a knowledge of the properties of similar triangles, i.e. problems on "heights and distances." When the similarity of equiangular triangles has been grasped it will be evident to the scholars that the height of a flagstaff can be obtained by comparing the length of its shadow with that of the shadow of a post of known height. Thus a simple method for determining the height of inaccessible places is obtained.

Similar Triangles

Similar triangles form the best starting point in the general treatment of the idea of similarity. Pupils soon grasp the fact that, if triangles are equiangular, their corresponding sides are all in the same proportion.

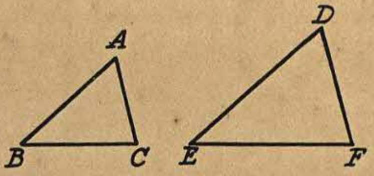


FIG. 4
Similar Triangles

Thus, if ABC and DEF (Fig. 4) are two equiangular triangles, then the ratios—

$$\frac{AB}{DE}, \frac{BC}{EF}, \frac{AC}{DF}$$

are all equal.

This may be experimentally investigated by means of a series of parallel lines, as in Fig. 5, drawn to form a series of similar triangles ABC, AB_1C_1, AB_2C_2, etc. Here the pupil may verify, by actual measurement, that AB, AB_1, AB_2; AC, AC_1, AC_2; BC, B_1C_1, B_2C_2 are all in the same proportion.

Similarly, the rods and shadows mentioned in the extract from the *Suggestions*, quoted above, are illustrated in Fig. 6. Here the shadows AB, AB_1, AB_2, AB_3, etc., of the upright posts (represented by CB, C_1B_1, C_2B_2, C_3B_3, etc.) are strictly proportionate to the height of the posts, i.e.—

$$\frac{AB}{CB}=\frac{AB_1}{C_1B_1}=\frac{AB_2}{C_2B_2}=\frac{AB_3}{C_3B_3}, \text{ etc.}$$

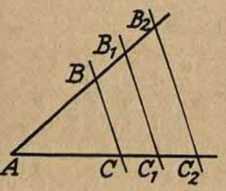


FIG. 5
Proportion Demonstrated by Parallels

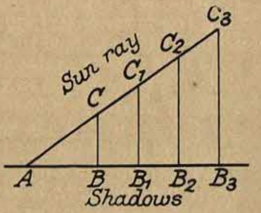


FIG. 6
Proportion: Rods and Shadows

As soon as the fundamental principle is grasped, innumerable examples, both geometrical and arithmetical, are possible.

The whole subject of proportionate division has a geometrical basis in these same properties of similar triangles. As an example, we may take the division of any line into any number of equal parts.

EXAMPLE.

Divide a given line AB into five equal parts.

The method consists of drawing a second line AC, five convenient units long (Fig. 7). CB is then joined, and parallels are drawn through the equidistant points on AC. It follows that if the sections of AC are equal, and the parallels are carefully drawn, then, by the properties of similar triangles, AB will also be divided into five equal parts.

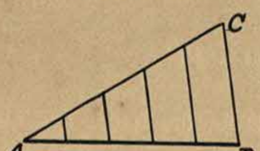


FIG. 7
Division of a Line into Equal Parts

Alternatively, two lines AC and BD each consisting of the same five units may be drawn parallel to each other, as in Fig. 8, and the equidistant points on each line joined. This will again divide any line AB into five equal parts, on the principle of similar triangles.

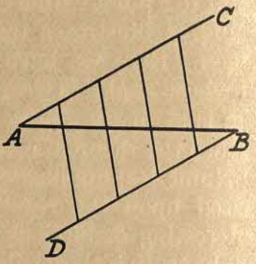


FIG. 8
Alternative Method of Division

Similar methods may be applied to the division of a line in any given proportion.

EXAMPLE.

Divide any line AB in the ratio 2 : 3.

Figs. 9 and 10 illustrate clearly how this may be done.

In Fig. 9, any line ADC is drawn such that $AD = 2$ units and $DC = 3$ units. CB is joined, and DE is drawn parallel to CB. It follows that $\frac{AE}{EB} = \frac{2}{3}$, by the principle of similar triangles.

Fig. 10 shows the alternative method, the investigation of which may be left to the pupil.

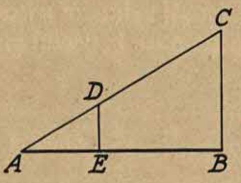


FIG. 9
Division of a Line in a Given Ratio

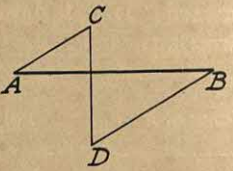


FIG. 10
Alternative Method

It is most important, in the case of similar figures, that the pupil should realize that the proportionality applies to *any* corresponding lines in the figure. Thus, in the case of similar triangles, it follows that if the bases and the sides are in the ratio 2 : 3, then, the *heights* of the triangles are also in the ratio 2 : 3.

The particular case of similar *right-angled* triangles will need special attention, and the investigation of the special case shown in Fig. 11 (where AD is drawn from the right angle at A, at right-angles to BC) will lead older pupils to a knowledge of the important principle of "mean proportion." Beginners will note, from actual measurement of sides and angles, that Fig. 11 shows *three* similar triangles, i.e. ABC, ABD, and ACD. It may readily be deduced that these three triangles are equiangular; it follows, therefore, that they are similar. By ordinary methods it is then easily deduced that the rectangle BD, DC is equal to the square on AD, a result which we shall see is of great importance later in describing, geometrically, squares which are multiples or submultiples of given squares.

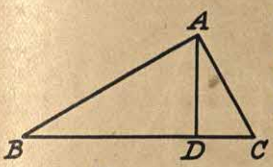


FIG. 11

Similarity in Right-angled Triangles

Similar Figures other than Triangles

We have noted that, if triangles are equiangular, they are always similar, i.e. they have proportionate dimensions. In figures other than triangles pupils will readily note that the existence of equal angles *alone* is not sufficient to establish similarity. Thus the two pentagons (Fig. 12) are equiangular, but not similar.

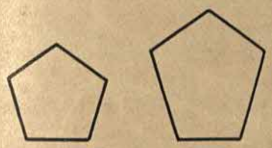


FIG. 12

Equiangular Pentagons which are not Similar

It thus follows that, for figures other than triangles, it is necessary to have both equal angles *and* proportionate dimensions, before similarity can be assumed. Thus all squares are similar to each other, but all rectangles are not. This accounts for the common fallacy of the picture-frame constructed of equal width all round (see Fig. 13).

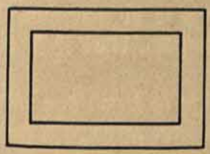


FIG. 13

Picture Frame Fallacy

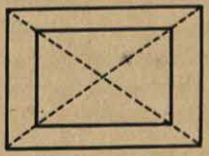


FIG. 14

Similar Rectangles

Here it is frequently wrongly assumed that the outer rectangle and the inner rectangle must be similar, whereas the simplest investigation or measurement will indicate that the ratios of the length to the width cannot be the same in each case, if the width of the frame is the same all round.

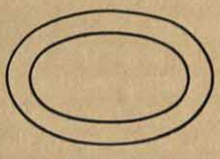


FIG. 15

Ellipse Fallacy

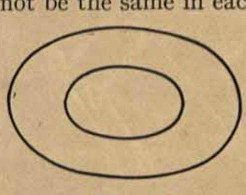


FIG. 16

Similar Ellipses

On the other hand, the two rectangles shown in Fig. 14 *are* similar, since they are based on the diagonals of the larger rectangle, and the principle of similar triangles therefore applies. It will be noted, however, that the width of the frame is not now the same on all sides.

Similarly, while all circles are obviously similar, the fallacy indicated above in the case of rectangles is also possible in the case of curved figures such as ellipses. Thus the two ellipses in Fig. 15 are *not* similar, because their major and minor axes are not proportionate, whereas the two ellipses in Fig. 16 *are* similar, because their axes are in each case in the same proportion.

Enlarging and Reducing

The principle of similarity is of great assistance in enlarging or reducing lines and figures.

Thus, if it is required to enlarge or reduce a given figure, this may be easily accomplished by the methods indicated below—

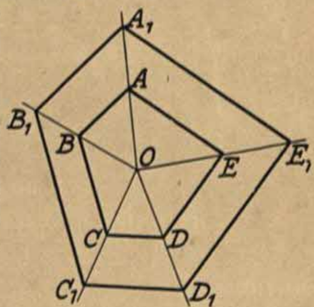


FIG. 17

Enlarging and Reducing I: Construction I

METHOD I

Any point O is taken within the given figure, and rays are drawn through the angular points of the figure, as in Fig. 17. Parallels are then drawn to each side of the given figure. It follows, by the principle of similar triangles, that the new figure $A_1B_1C_1D_1E_1$ is similar in all respects to the original figure *ABCDE*.

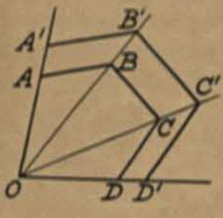


FIG. 18
Alternative Construction

If the point *O* is taken in a limiting position, i.e. at one of the angular points, as in Fig. 18, then the construction is slightly simpler. Parallels across the rays are drawn as before, and the new figure $OA^1B^1C^1D^1$ is in every respect similar to the original, *OABCD*.

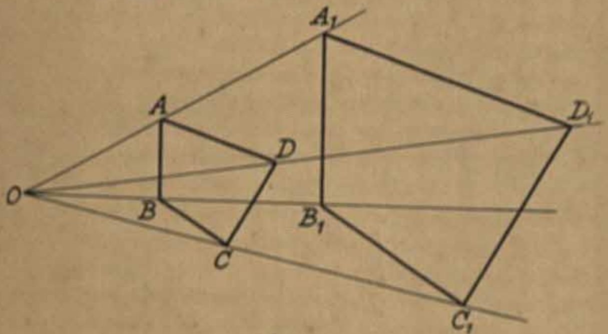


FIG. 19
Enlarging and Reducing II

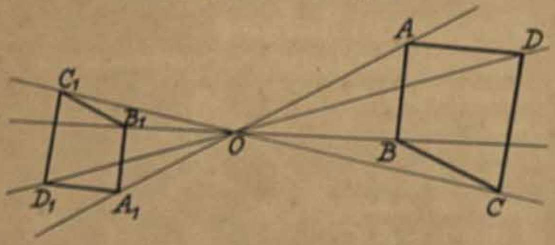


FIG. 20
Extension of Construction II

METHOD II

Any point *O* is taken outside the given figure *ABCD*, and rays are drawn as before. Parallels are then drawn to each side of the given figure, to give the larger similar figure $A_1B_1C_1D_1$ (Fig. 19).

If the rays are produced in the *opposite* direction, as in Fig. 20, it is interesting to note that the resultant figure $A_1B_1C_1D_1$ is similar but reversed in position.

This process is of great assistance in many geometrical problems. We illustrate with two well-known problems.

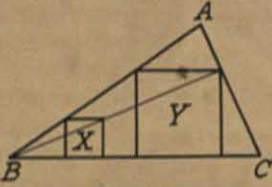


FIG. 21
Application to Problem (1)

Problem (1). *In a given triangle ABC, inscribe a square with one side collinear with a side of the triangle.*

In the triangle *ABC* (Fig. 21) *any* square is drawn so that one side is collinear with a side of the triangle.

This square (*X*) is then projected, by the method just described, to the position *Y* and the problem is completed, since it is obvious, by the principle of similar triangles, that if *X* is a square then *Y* is also a square.

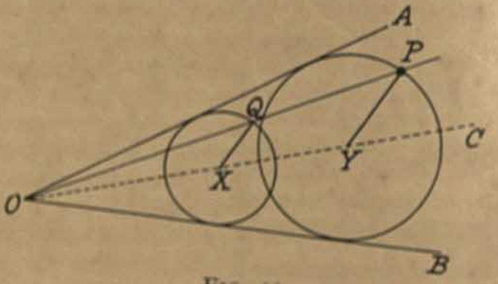


FIG. 22
Application to Problem (2)

Problem (2). *Draw a circle to touch two intersecting straight lines and to pass through a given point.* (See Fig. 22.)

Let *OA* and *OB* be the lines, and *P* the point.

Clearly, the centre of the required circle must be upon the bisector of the angle *AOB*, i.e. upon *OC*. Take any centre *X* on *OC* and describe a circle to touch *OA* and *OB*. Join *OP*, cutting the circle, just drawn, at *Q*. Now draw *QX*, and

PY parallel to QX. Then Y is the centre of the circle required.

We leave the simple proof to the reader.

Areas of Similar Figures

Of immense importance in mathematics is the principle controlling the areas of similar figures.

The principle is a simple one—

Areas of similar figures are proportional to the squares on corresponding dimensions.

This is readily grasped in the case of squares, and pupils find no difficulty in realizing that if the sides of squares are in the proportion 1 : 2 : 3, etc., then the corresponding areas are in the proportion 1 : 4 : 9, etc. Similarly, for circles, it follows, from the formula $2\pi r$, that if the radii are in the proportion 1 : 2 : 3, etc., then the areas are in the proportion 1 : 4 : 9, etc. This may be investigated with beginners both numerically and graphically. The principle in the case of triangles will prove slightly more difficult for beginners, but it can be shown, by drawing, as in Fig. 23, that similar triangles whose bases (or sides) are in the proportion 1 : 2 : 3 will have areas in the proportion 1 : 4 : 9.

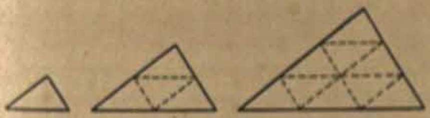


FIG. 23

Areas of Similar Triangles

Here the dimensions of the three triangles are in the proportion 1 : 2 : 3, and the drawing shows clearly that the areas are in the proportion 1 : 4 : 9.

We shall deal later with the curve of squares, in the section on Graphs.

Volumes of Similar Solids

The relation existing between the volumes of similar solids is a further important aspect of the principle of similarity.

This principle may be briefly stated as follows—

The volumes of similar solids are proportionate to the cubes *of corresponding linear dimensions.*

This may well be investigated by beginners through the medium of the cube. Here, by means of inch cubes it may be made apparent that the number of cubes required to build larger cubes increases very rapidly, e.g.—

Size of Cube.	*No. of Inch-cubes Required.*
2 in. edge	8 (2^3)
3 in. "	27 (3^3)
4 in. "	64 (4^3)
5 in. "	125 (5^3)
and so on.	

From this, they may proceed to any rectangular volume. Thus they will realize that if such a volume is cut by a series of cuts through the middle-point of every edge, as shown in Fig. 24, then it is divided into *eight* smaller but similar blocks.

The above principles are of course applicable to spheres. Hence it follows that if a series of spheres have their radii (or diameters) in the proportion 1 : 2 : 3, etc., then their surfaces are in the proportion 1 : 4 : 9, etc., and their volumes are in the proportion 1 : 8 : 27.

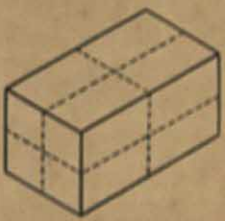


FIG. 24

Volumes of Similar Solids

Numerous cases of real quantities which vary as the squares or as the cubes of other quantities will be met with in connection with the instruction in science, and the older pupils should explore these fully, using all possible methods of investigation—arithmetical, algebraical, graphical, and geometrical. In this interesting way they will gradually realize that mathematics is a logical whole, and is merely divided for convenience into several parts.

V. Measurement of Area and Volume

This section of the syllabus suggested by the official *Handbook of Suggestions* has already been dealt with in considerable detail in this book and we therefore proceed to the next section.

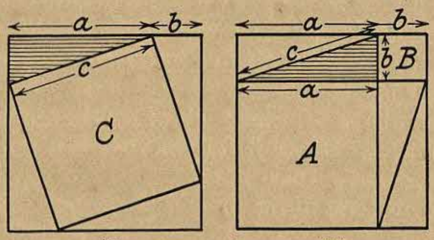
VI. The Theorem of Pythagoras

The importance of this fundamental theorem in any mathematical syllabus cannot be over-estimated. The theorem is usually stated in the following form—

The sum of the squares on the two sides of any right-angled triangle, which contain the right angle, is equal to the square on the hypotenuse.

For beginners, particularly Senior School pupils, the well-known proof given in *Euclid*, Book I, Prop. 47, is hardly suitable, but many methods of demonstrating the truth are available for teachers.

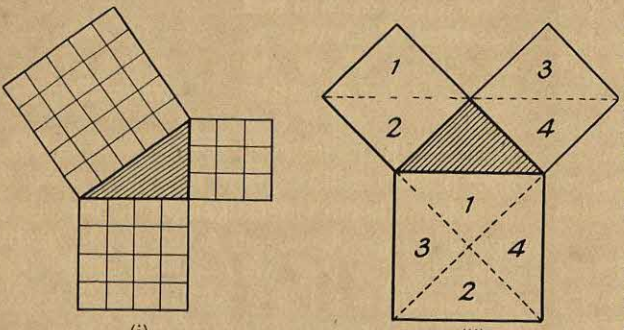
The following demonstration will be found as useful as any.



(i) FIG. 25 (ii)

Simple Demonstration of Pythagoras

In Fig. 25 the two large squares are identical in area. Fig. 25 (i) shows one of the large squares divided into four equal right-angled triangles, together with the square *C*. Fig. 25 (ii) shows the same four equal right-angled triangles, with two squares *A* and *B*.



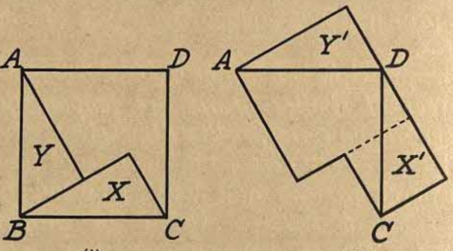
(i) FIG. 26 (ii)

Demonstrations of Particular Cases

It follows, from inspection, that the square *C* is equal to the sum of the squares *A* and *B*, which demonstrates the theorem.

Particular cases of the theorem are shown in Fig. 26 (i) and (ii), but the teacher should beware of assuming that these special cases are *general* proofs.

Fig. 26 (i) shows the particular case of the 3 : 4 : 5 triangle (which is known to be right-angled), and accordingly it can be readily seen, as in the drawing, that the squares on the sides (9 + 16) are equal to the square on the hypotenuse (25).



(i) FIG. 27 (ii)

Paper-cutting Demonstrations

Fig. 26 (ii) represents the particular case of the right-angled isosceles triangle, and the drawing indicates how it may be readily shown, by paper-cutting, that the squares on the two sides, if cut into triangles, will cover exactly the square on the hypotenuse.

Many methods for dissecting the areas of the two squares on the sides so as to cover the square on the hypotenuse have been evolved and will be found in any modern textbook of geometry. The simpler cases should be used as paper-cutting exercises to demonstrate still further this beautiful theorem.

The converse process, i.e. converting the square on the hypotenuse into the corresponding two smaller squares, is not so often practised, but a simple method by which this may be done is given in Fig. 27 (i) and (ii).

In Fig. 27 (i) the square *ABCD* is clearly the square on the hypotenuse of either of the equal right-angled triangles, *X* or *Y*.

Fig. 27 (ii) shows the triangle *Y* cut out and rotated round *A* to its new position Y^1, and similarly *X* is rotated round *C* to its new position X^1. It is an interesting exercise to demonstrate, or prove, that Fig. 27 (ii) represents the squares on the two sides of the triangle *X* or *Y*. When this is done we have demonstrated that the square on the hypotenuse [Fig. 27 (i)] is equal to the sum of the squares on the sides [Fig. 27 ii].

NUMERICAL APPLICATIONS

As soon as the theorem is understood, it is possible to set numerical examples based upon it. These will take mainly two forms—

(*a*) Finding the hypotenuse, given the lengths of the two sides.

(*b*) Finding the third side, given the length of the hypotenuse and one side.

In the ordinary way, it will usually be necessary to find the square root of a number, as in the following—

(i) *Given sides* 5 *and* 6—*find hypotenuse.*

Here the square on the hypotenuse is (25 + 36) or 61, hence the hypotenuse is $\sqrt{61}$, which can be evaluated by the ordinary rule, or by logarithms.

(ii) *Given the hypotenuse,* 8, *and one side* 5—*find the remaining side.*

Here the square on the remaining side is (64–25) or 39, hence the length of the remaining side is $\sqrt{39}$. Teachers, however, find that, for beginners, integral solutions, such as the 3 : 4 : 5 triangle, or the 5 : 12 : 13 triangle, are most useful in setting numerical problems, and we shall accordingly discuss these whole-number solutions at some length.

Two very old rules, easily remembered, are here given for finding integral solutions.

METHOD I

Solutions based on odd numbers.

This solution depends upon the simple identity $n^2 + 2n + 1 = (n + 1)^2$. This identity contains two perfect squares: n^2 and $(n + 1)^2$. The third square may be found by taking, for the number $(2n + 1)$, all the odd squares in order, as follows—

$2n + 1$	n	$n^2 + 2n + 1 = (n + 1)^2$	Corresponding Triangle
9	4	16 + 9 = 25	3 : 4 : 5
25	12	144 + 25 = 169	5 : 12 : 13
49	24	576 + 49 = 625	7 : 24 : 25
81	40	1,600 + 81 = 1,681	9 : 40 : 41
121	60	3,600 + 121 = 3,721	11 : 60 : 61

This series may be continued indefinitely, and any multiples of the numbers in the last column will also give a corresponding triangle. Thus the triangles whose sides are 6, 8, 10, or 10, 24, 26, are also right-angled.

METHOD II

Solutions based on even numbers.

These are based upon an equally simple identity as follows—

$$(n^2 - 1)^2 + (2n)^2 = (n^2 + 1)^2$$

which may also be expressed in words, i.e. "Take any even number $(2n)$. Square its half (n) and add 1, $(n^2 + 1)$; square its half (n) and subtract 1, $(n^2 - 1)$. The three numbers thus obtained will correspond to the sides of right-angled triangles." Solutions are given as follows—

$2n$	$n^2 - 1$	$n^2 + 1$	Corresponding Triangle
4	3	5	3 : 4 : 5
6	8	10	3 : 4 : 5
8	15	17	8 : 15 : 17
10	24	26	5 : 12 : 13
12	35	37	12 : 35 : 37
14	48	50	7 : 24 : 25
16	63	65	16 : 63 : 65

As in the former case, so this series, too, may be continued indefinitely.

Every possible integral solution is of course included in the following identity—

$$k\{(m^2 - n^2)^2 + 4m^2n^2\} = k(m^2 + n^2)^2$$

where k, m, and n have any integral values. Pupils, however, will enjoy the exploration of the simpler series given above before being introduced to the more general expression.

EXTENSION OF THE THEOREM OF PYTHAGORAS TO RECTANGULAR SOLIDS

The rectangular solid provides an easy and interesting application of the theorem of Pythagoras to three-dimensional geometry.

In plane geometry we know that the diagonal of a rectangle, whose sides are a and b, is $\sqrt{a^2 + b^2}$ (Pythagoras) (Fig. 28).

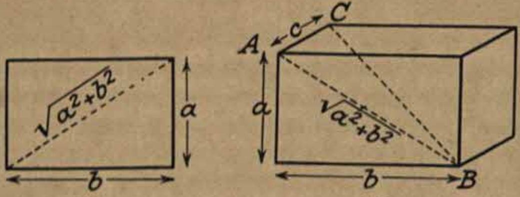
If this rectangle is now considered to be one face of a parallelepiped (rectangular solid) whose third dimension is c [Fig. 28 (ii)], it will be seen that the long diagonal CB is clearly the hypotenuse of the right-angled triangle BAC.

Hence $(CB)^2 = (AB)^2 + (AC)^2$

or $(CB)^2 = a^2 + b^2 + c^2$

Hence the diagonal of a rectangular solid is found by finding the square root of the sum of the three dimensions.

Example. Find the long diagonal of a box whose dimensions are 6 *in.,* 3 *in., and* 2 *in.* According to the formula just given, this diagonal should be $\sqrt{36 + 9 + 4} = \sqrt{49} = 7$.



(i) FIG. 28 (ii)

Pythagoras Applied to Rectangular Solids

As in the case of the right-angled triangle, so in the case of the solid figure just discussed, teachers may find it useful to be prepared with a series of integral values for the equation

$$a^2 + b^2 + c^2 = d^2$$

The following will give whole-number solutions for all positive values of n—

$$(n)^2 + (n+1)^2 + \{n(n+1)\}^2$$
$$= \{n(n+1) + 1\}^2$$

Example.

n	$n+1$	$n(n+1)$	Corresponding Solid	Diagonal
1	2	2	1 : 2 : 2	3
2	3	6	2 : 3 : 6	7
3	4	12	3 : 4 : 12	13
4	5	20	4 : 5 : 20	21
5	6	30	5 : 6 : 30	31

This series, too, may be continued indefinitely.

THE IDENTITY $a^2 - b^2 = (a + b)(a - b)$

This identity is most useful in determining the third side of a right-angled triangle, for, if a be the hypotenuse, and b be one of the sides, then, by Pythagoras, the square on the third side is equal to $(a^2 - b^2)$.

The truth of this identity may be explored numerically, algebraically, and geometrically.

Arithmetically.

$$2^2 - 1^2 = 3 = (2 + 1)(2 - 1)$$
$$3^2 - 2^2 = 5 = (3 + 2)(3 - 2)$$
$$4^2 - 3^2 = 7 = (4 + 3)(4 - 3)$$

and so on.

Further, for any values, the formula may be verified, e.g. $5^2 - 2^2 = 21 = 7 \times 3 = (5 + 2)(5 - 2)$.

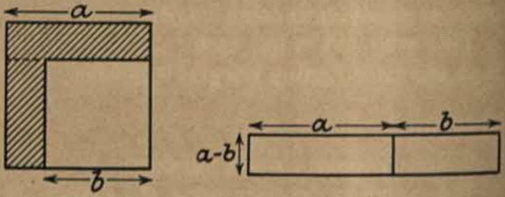
Algebraically.

The application of the ordinary laws of multiplication gives the result required: e.g.—

$$\begin{array}{l} a + b \\ a - b \\ \hline a^2 + ab \\ \qquad - ab - b^2 \\ \hline a^2 \qquad\quad - b^2 \\ \hline \end{array}$$

Geometrically.

In Fig. 29 (i) the shaded part is clearly equal to $a^2 - b^2$. Fig. 29 (ii) shows this shaded area cut out and rearranged to form the rectangle $(a + b)(a - b)$, which demonstrates the truth of the identity.



(i) FIG. 29 (ii)

Geometrical Proof of Identity of $a^2 - b^2$

This identity is not only useful in calculation but is of great value in the numerical solution of indeterminate equations of the form—

$$x^2 - y^2 = k$$

Example. Find all the pairs of whole numbers whose squares differ by 15.

Here $x^2 - y^2 = 15$

Using factors, we have

$$(x + y)(x - y) = (15)(1) \text{ or } (5)(3)$$

Taking 15 and 1, we have

$$x + y = 15$$
$$x - y = 1$$

which, by addition and subtraction, gives $x = 8$ and $y = 7$. Taking 5 and 3, we have

$$x + y = 5$$
$$x - y = 3$$

which, by addition and subtraction, gives $x = 4$, $y = 1$. Hence the required solutions are (i) 4 and 1, and (ii) 8 and 7.

The Extraction of a Square Root

We have already indicated that, while whole-number solutions of $a^2 + b^2 = c^2$ may be found and used as the basis of problems, it will usually happen that the use of the Pythagorean relation in a calculation will require the extraction of a square root.

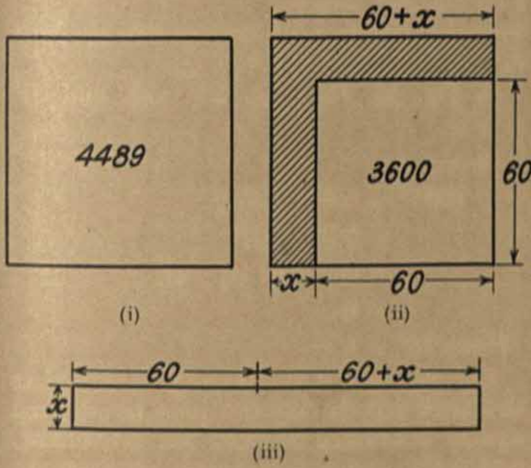


FIG. 30

Demonstration of Square Root

If the number is a perfect square, its square root may be found by the inspection of its prime factors, but usually, for larger numbers or for non-factorizable numbers, it will be necessary to apply some general method, e.g. one of the following—

(*a*) The usual "rule."
(*b*) Logarithms.
(*c*) The Slide rule.

THE ORDINARY RULE

The ordinary rule for finding square roots to any required accuracy is usually easily taught and learned, and children enjoy its application.

Example 1. *Find the square root of* 4489.

This is worked by rule as follows—

```
     4489|67
     36
 127| 889
    | 889
```

The rule may be demonstrated as follows—

Assume that any square [Fig. 30 (i)] represents the given number 4489. From this square we cut away the largest possible square ending in 00, i.e. 3600 [Fig. 30 (ii)]. This leaves the shaded part shown in Fig. 30 (ii) which is clearly equal to 4489 − 3600, or 889. But this shaded part can be rearranged as Fig. 30 (iii) or $(120 + x)(x) = 889$ and, by trial, x is found to be 7.

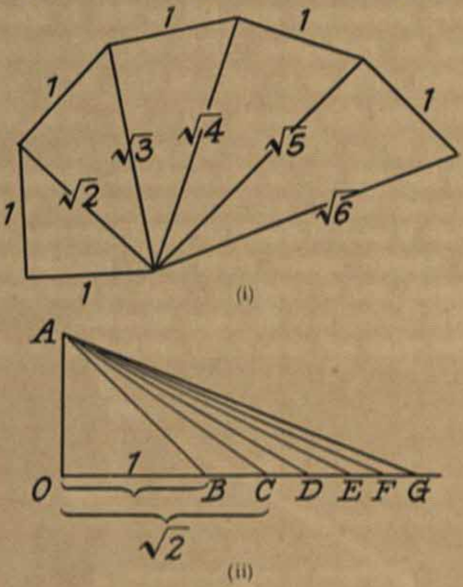


FIG. 31

Square Roots: Geometrical Constructions

Extraction of square root by logarithmic methods, including the slide rule, will be noted later.

SQUARE ROOTS BY GEOMETRICAL METHODS

The Theorem of Pythagoras affords most interesting opportunities for the determination of square roots of numbers by geometrical methods.

Fig. 31 (i) indicates how the square roots of the natural numbers may be successively determined. We leave the "proof" to the reader.

Starting with any convenient unit, and drawing the right-angled triangles as shown, the successive hypotenuses give $\sqrt{2}$, $\sqrt{3}$, $\sqrt{4}$, $\sqrt{5}$, etc., in order. The figure may be continued to any desired extent.

Fig. 31 (ii) indicates how these successive roots may be arranged more conveniently in a straight line.

Any convenient unit, OA or OB, is taken. Then, by Pythagoras, $AB = \sqrt{2}$. OC is next marked off equal to AB, and then $AC = \sqrt{3}$. Continuing this process, $OD = \sqrt{4}$ (or 2), $OE = \sqrt{5}$, $OF = \sqrt{6}$, $OG = \sqrt{7}$, and so on.

If the unit OA or OB is chosen sufficiently large, say 10 cm., and paper squared in millimetres is used, it should be possible to read off the various square roots with considerable accuracy, and to construct a scale of these roots within the limits of the paper available.

But other and more direct methods are available for determining the square root of any given number, still using the theorem of Pythagoras.

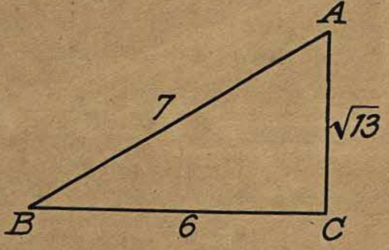


FIG. 32

To Find $\sqrt{13}$

Remembering the identity—

$$a^2 - b^2 = (a + b)(a - b),$$

we note that any number may be expressed as the difference of the squares of two quantities which themselves differ by unity.

Thus—

$$\begin{aligned} 17 &= (9 + 8)(9 - 8) \\ &= 9^2 - 8^2 \end{aligned}$$

and

$$\begin{aligned} 24 &= (12\tfrac{1}{2} + 11\tfrac{1}{2})(12\tfrac{1}{2} - 11\tfrac{1}{2}) \\ &= (12\tfrac{1}{2})^2 - (11\tfrac{1}{2})^2 \end{aligned}$$

Applying these facts geometrically, we have exceedingly simple methods for determining square roots.

Example. Find graphically the value of $\sqrt{13}$.

Method. Construct a right-angled triangle whose hypotenuse is 7 and one side 6. Then the third side is $\sqrt{13}$ (see Fig. 32).

Here $AB = 7$, $BC = 6$, and we leave it to the reader to deduce that AC must be $\sqrt{13}$.

Example. Find graphically the value of $\sqrt{10}$.

Method. Construct a right-angled triangle whose hypotenuse is $5\frac{1}{2}$ and one side $4\frac{1}{2}$. Then the third side is $\sqrt{10}$ (see Fig. 33).

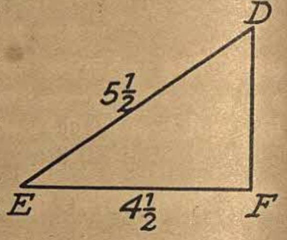


FIG. 33

To Find $\sqrt{10}$

In Fig. 33, $DE = 5\frac{1}{2}$, $EF = 4\frac{1}{2}$, and $DF = \sqrt{10}$.

Proof—

$$\begin{aligned} (DF)^2 &= (DE)^2 - (EF)^2 \\ &= (5\tfrac{1}{2})^2 - (4\tfrac{1}{2})^2 \\ &= (5\tfrac{1}{2} + 4\tfrac{1}{2})(5\tfrac{1}{2} - 4\tfrac{1}{2}) \\ &= 10 \end{aligned}$$

Hence $DF = \sqrt{10}$.

The principle of the mean proportional as associated with the semicircle provides other and equally interesting methods for determining, graphically, square roots of given numbers, and we shall accordingly deal with these in the next section.

VII. Angle-Properties of Circles

These properties readily lend themselves to experimental investigation. Among the important theorems to be explored in this connection are the following—

1. *The angle subtended by any arc at the centre is always double the angle subtended at the circumference.*
2. *Angles in the same segment are all equal.*
3. *The opposite angles of any quadrilateral inscribed in a circle are always equal to two right angles.*

4. *The angle in a semicircle is always a right angle.*

Numerous interesting constructions may be based upon these truths, and particularly useful are those involving tangents and mean proportionals. Thus the facts that the angle in a semicircle is a right angle, and that the tangent is always at right angles to the radius at the point of contact, give the well-known construction for drawing a tangent from a given point to a given circle, illustrated in Fig. 34.

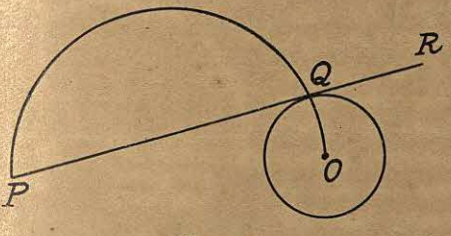


FIG. 34

To Draw a Tangent from Given Point to Given Circle

P is any point, and O is the centre of the circle. A semicircle drawn on PO as diameter fixes the point Q, and PQR is the tangent required, since PQO is a right angle.

Mean Proportion and the Semicircle

Since the angle in a semicircle is always a right angle, it follows that any triangle in a semicircle, having the diameter as its base, must be a right-angled triangle. Thus the triangle ABC (Fig. 35) is right-angled at A.

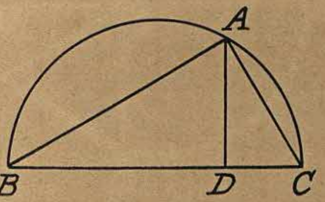


FIG. 35

Construction for Mean Proportional

AD is then drawn at right angles to BC.

It can readily be established that the two triangles ABD and ACD are equiangular and, therefore, similar.

It then follows that $\frac{BD}{AD} = \frac{AD}{DC}$, or that

$$BD, DC = (AD)^2$$

AD being called, because of this relation, a mean proportional between BD and DC.

This important fact enables us at once—

(*a*) To construct a square equal to any given rectangle;

(*b*) To find graphically the square root of any given number.

These two problems are merely two aspects of the same construction.

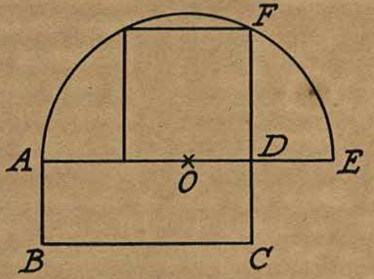


FIG. 36

To Construct a Square Equal to Given Rectangle

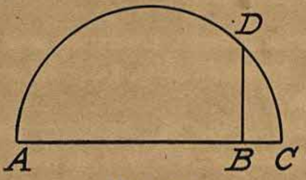


FIG. 37

Construction for Finding $\sqrt{6}$

Method for (*a*)

Fig. 36 illustrates the method by which a square may be constructed equal to any given rectangle.

In the diagram, $DE = DC$, and $OA = OE =$ radius of the semicircle.

It follows that the rectangle AD, DE (or AD, DC) is equal to the square on DF.

Method for (*b*)

Example. Find $\sqrt{6}$ *graphically.*

In Fig. 37, $AB = 6$ units, and $BC = 1$ unit. A semicircle is drawn on AC as diameter, and BD, drawn at right angles to AC, then represents $\sqrt{6}$. We leave the proof to the reader.

The same result could also be obtained by making $AB = 3$ and $BC = 2$.

Most interesting of all the problems which may be solved by this construction is the general problem of describing a square which is n times the area of a given square, when n is any positive number, integral or fractional.

All that is necessary is to describe a semicircle on a diameter consisting of the sum of the side of the original square and n times this length (see Fig. 38).

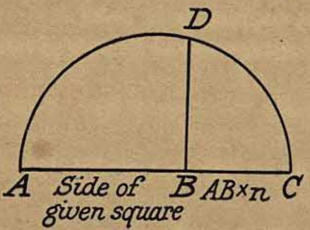


FIG. 38

To Construct Square n Times Area of Given Square

Here AB is the side of the given square, and BC is equal to $AB \times n$. Then the square on BD is equal to n times the square on AB, whether n is a whole number or a fraction.

Particular Examples

1. *Describe a square having an area of 3 sq. in.*

In this example (Fig. 39), $AB = 1$ in., and $BC = 3$ in.

It follows, using the ordinary construction, that the square on BD has an area of 3 sq. in.

2. *Describe a square having one-third the area of a given square.*

In this construction (Fig. 40) BC is made equal to one-third of the length of the side (AB) of the original square, and BD is accordingly the side of a square having one-third the area of the square on AB.

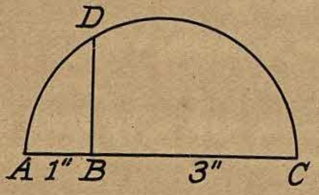


FIG. 39

To Construct Square of Area 3 sq. in.

It will thus be seen that the applications of the principle of mean proportion are endless in number and of the most extraordinary interest. We add one more example to show its beauty and its value.

Problem I

Describe an equilateral triangle which shall have the same area as a given triangle.

Fig. 41 explains the simple construction. ABC is the given triangle. An equilateral triangle DCE is drawn, having the same altitude as ABC. A semicircle is then drawn on BE as diameter, and CF is then the side of the equilateral triangle required.

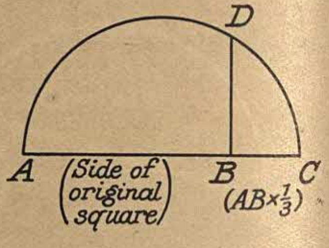


FIG. 40

To Construct Square of $\frac{1}{3}$ Area of Given Square

To prove that the area of $\triangle$ ABC is equal to the area of $\triangle$ CFG—

$\triangle ABC : \triangle DCE :: BC : CE$

But $BC : CF :: CF : CE$

Hence $BC : CE :: (CF)^2 : (CE)^2$

But $(CF)^2 : (CE)^2 :: \triangle CFG : \triangle DCE$

Hence

$\triangle ABC : \triangle DCE :: \triangle CFG : \triangle DCE$

$\therefore \triangle ABC = \triangle CFG.$

Finally, pupils who have progressed in algebra as far as quadratic equations may use the same construction for the graphic solution of quadratic equations as follows—

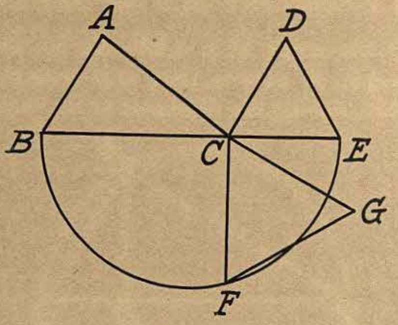


FIG. 41

To Construct an Equilateral Triangle of Same Area as a Given Triangle

Example. Solve the equation $x^2 - 7x + 12 = 0$. Here, by inspection, we see that the sum of the roots is 7 and the product of the roots is 12. The problem is to find these roots graphically, i.e. to find two lines whose sum is 7 and whose product is 12.

Fig. 42 indicates the method. A line *AB* is drawn 7 units long and a semicircle described on it. At *B* (or at *A*) a line *BC* is drawn at right angles to *AB*, and $\sqrt{12}$ units long. At *C* a line *CD* is drawn parallel to *AB* to cut the semicircle in *D*, and *DE* is drawn perpendicular to *AB*. Then *AE* and *EB* are the required roots of the quadratic equation (in this case, 4 and 3).

Readers may adapt this construction to the division of the line *AB* *externally* at *E*, so that $AE, EB = (DE)^2$, and they will then find a method of solving an equation of the form

$$x^2 - 7x - 18 = 0$$

where 7 represents the *difference*, and 18 the product of the two roots.

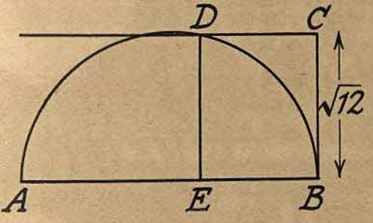


FIG. 42

Graphic Solution of Quadratic Equation

All the above interesting deductions from the simple principles of similar triangles and the Pythagorean theorem indicate the close connection (already repeatedly emphasized) existing between the various parts of mathematics.

VIII. *Simple Solids—Plans and Elevations*

We have already referred, in dealing with volume, to the construction of some of the simpler solids. In particular, we dealt incidentally with the triangular pyramid. In the particular instance where each face of this solid is an equilateral triangle, we have the simplest case of a regular polyhedron. These polyhedra are so few in number, and of such mathematical interest, that they may well be included in any course of constructive solid geometry for the older boys in a Senior School. We give, accordingly, their names and "nets" for the purpose of the construction of models.

1. REGULAR TETRAHEDRON

This has four faces, four vertices, and six edges. Its "net" is as follows—

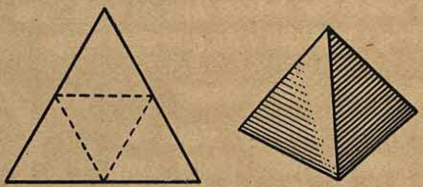


FIG. 43

Regular Tetrahedron and "Net"

In the solid, *three* equilateral triangles meet at each vertex.

2. REGULAR OCTAHEDRON

This also is based on equilateral triangles, but in this case there are eight faces, six vertices, and twelve edges. Its "net" is as follows—

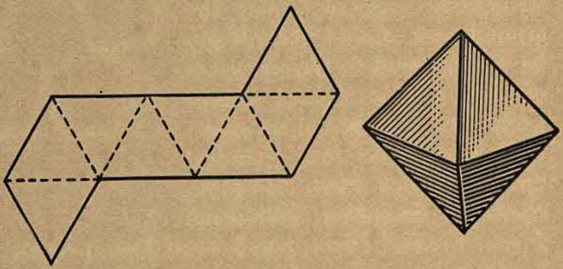


FIG. 44

Regular Octahedron and "Net"

In the solid, four equilateral triangles meet at each vertex.

3. REGULAR ICOSAHEDRON

This solid has twenty faces, twelve vertices, and thirty edges. Its net is shown in Fig. 45 on p. 88.

In this solid, five equilateral triangles meet at each vertex.

4. THE CUBE

This has been already explored in the section on Volume, and its "net" is given on p. 64.

5. Regular Dodecahedron

Every face of this solid is formed of a regular pentagon. It has twelve faces, twenty vertices, and thirty edges. Its "net" is shown in Fig. 46 below.

It is excellent practice for pupils to construct the above solids in cardboard, bending the cardboard along the dotted lines of each "net" and fastening the edges with gummed strips.

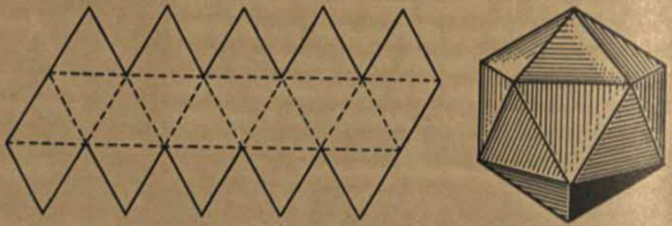


Fig. 45

Regular Icosahedron and "Net"

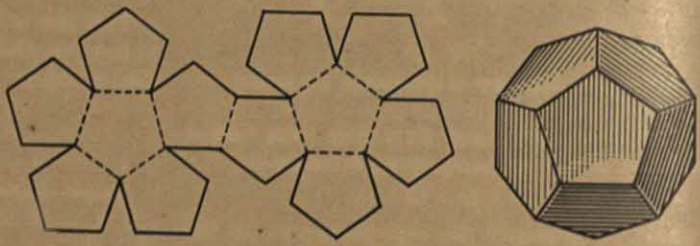


Fig. 46

Regular Dodecahedron and "Net"

Plans and Elevations

We have already dealt to some extent with plans and elevations in the introductory paragraphs to this chapter on Geometry (see p. 71). We shall now develop the subject in slightly greater detail.

The process known as "plan and elevation" is the most practical method yet devised for representing solid objects on paper. The method is fundamental for builders and constructional engineers, and the groundwork should accordingly be well covered in the last years of any Senior School course which has a technical or industrial bias. The few technical terms, such as *Plan, Elevation, Plane of Projection, Horizontal Plane, Vertical Plane,* and *Ground Line,* present no difficulty, and pupils soon grasp the method and readily draw plans and elevations in connection with their handicraft work. The simpler solids, cubes, prisms, cylinders, cones, etc., are easily available for this more elementary work, and pupils should draw these from various view-points by the accepted methods of projection. They should be further asked to explore side elevations, end elevations, and sections. Much of the work will be co-ordinated with the Instruction in Handicrafts.

But this subject of plans and elevations, particularly plans, may be extended far beyond the ordinary limits of the simpler solids, as the following most useful paragraph from the *Handbook of Suggestions* will indicate—

> The applications of arithmetic and geometry to the making and reading of plans and elevations are interesting and instructive, and they are likely to form a valuable aid to the teaching of geography. Position may be dealt with, in the first instance, by representing on a plan the relative position of three or more objects which lie close together on the floor of the schoolroom. Later on, their positions relative to the walls of the room may be considered, and similar exercises involving greater distances may be taken out of doors. For example, two base lines may be set out and the distances of various objects therefrom measured by the scholars. The objects chosen may, for instance, be stakes at the corners of an irregularly-shaped field, or along the edge of a pond. The scholars may represent the results of their measurements on squared paper, and thus plot out the outline of the field or pond, and by counting squares within the outline, they can then ascertain the area. Another exercise in out-of-door work is the measurement of the area of a field by the ordinary field-book method. Nor need exercises of this type be confined to linear measurements; the directions, relative to the points of the compass, of the imaginary lines drawn from the observer to various objects may be ascertained, first roughly by eye, and later, with more accuracy, by the use of a home-made plane-table. It has been found possible in some schools for the more advanced pupils to accomplish a rough survey of a suitable district in the neighbourhood of the school. (*Suggestions.*)

These excellent suggestions for field work in connection with the making of plans and maps should be incorporated into every Senior School syllabus, and it is of little consequence whether the work is labelled "Mathematics" or "Geography."

Summary

We have now indicated, in some detail, the main developments in geometry which appear to us to be possible in the Senior School. At once let it be understood that in dealing with this subject in schools everything will depend upon the ability and the enthusiasm of the teacher. The subject will of course be better dealt with, especially in its higher branches, by a qualified specialist teacher, and in every case the head teacher or teacher is advised to make a selection suitable to the type of school for which the syllabus is intended. Finally, it may be stated that much of the matter indicated in detail in the preceding sections is suitable alike for boys and girls, and it is hoped accordingly that this subject of geometry, in some at least of its many aspects, will not be neglected in girls' schools.

We shall conclude this section by indicating briefly a few further developments which should be possible with older pupils, possibly those above the age of fourteen, in selective Central Schools.

Theoretical Geometry

Much is here possible, beginning with the interesting subject of congruent triangles. Any modern textbook will suffice, and much real and valuable deductive work may be done with selected pupils, in which they are conducted through the ordinary sequence of theorems, thus codifying their knowledge, so far gained by empirical and logical methods, into a coherent and logical whole. This possibility is mentioned in the *Handbook of Suggestions* in the following terms—

> Teachers interested in the more theoretical aspect of the work can make this (i.e. congruent triangles) the starting point for much reasoned problem work, such as would be appropriate in Central Schools or Advanced Classes where school life is prolonged.

Loci

The subject of loci is a fascinating one in the hands of a capable teacher, and is rightly suggested in the *Handbook of Suggestions* as a possible subject of more advanced study—

> Simple problems involving the conception of geometrical loci may be introduced, and the rules for the construction of the parabola, hyperbola, and ellipse, treated as loci, may be explained and applied.

Problems involving loci are of infinite variety. We indicate here only a few of the more important—

1. *Find the locus of all points equidistant from two given points.*
2. *Find the locus of all points equidistant from two straight lines (these may be parallel or intersecting).*
3. *Find the position of a point equidistant from three given points not in the same straight line (this is a circle).*
4. *Find the locus of a point which moves so that its distance from a fixed point is always equal to its distance from a given straight line (this is a parabola).*
5. *Find the locus of a point which moves so that its distance from a fixed point is in a fixed ratio to its distance from a given straight line (this results in an ellipse or a hyperbola, according as the fixed ratio is less or greater than unity).*

Pupils should be encouraged to plot loci under given conditions, especially on squared paper, and thus approach, from first principles, the interesting study of curve-tracing as a valuable development of the ordinary plotting of graphs.

Scales: Plain and Diagonal

The construction of scales of all the ordinary kinds is a useful auxiliary to the more mechanical side of scale-drawing, and pupils may accordingly be required to extend their knowledge in this part of the subject.

Here they may learn the meaning of the term Representative Fraction (R.F.) as applied to scales, and may be required to construct scales on any convenient Representative Fraction to indicate distances up to any convenient limit.

Example. Construct a scale of $\frac{1}{4}$ *in. to the foot to show all distances up to* 4 *yd.*

Here the R.F. is clearly $\frac{1}{4} : 12$, or $\frac{1}{48}$, and the length of scale necessary is $\frac{1}{48}$ of 4 yd., or 3 in.

Thus a line 3 in. long, suitably graduated, gives the required scale.

Diagonal scales are convenient devices for making very small measurements as accurately as possible. If the drawing is accurate, measurements to at least two decimal places are usually possible. Space does not permit us to indicate how such scales are drawn and used, but illustrative examples will be found in any modern textbook of practical drawing.

The basis of construction is the simple principle of similar triangles, and we would ask all teachers to permit their more advanced pupils to construct a simple diagonal scale, one which will read, e.g. to hundredths of an inch. This is readily constructed if paper squared in inches and tenths is used as a basis.

Mechanical Drawing

Finally, in schools with a definite industrial or technical bias, room should be found, in the syllabus for the older boys, for work in the more definite drawing of machines and machine parts. This work, in the words of the *Suggestions*—

> gives further point to the work in solid geometry, with which it should be suitably linked up. The principle of the vernier callipers may be explained and the instrument used in the measurement of machine parts. Hand-sketches should be followed by dimensioned ruled drawings, and each boy allowed to make a "blue-print" of one of his ruled drawings.

We have devoted very considerable space above to the subject of Practical Drawing and Geometry because we feel that this is a subject capable of very considerable development in the new Senior Schools. Properly approached, the work cannot fail to be of infinitely greater value to the ordinary pupil than the endless arithmetical "sums" or meaningless algebraic manipulations which in some schools appear to occupy an undue share of the periods allotted to Mathematics.

ALGEBRA

AGREEMENT is now fairly general that the course in Arithmetic and Mathematics should include some sections of Elementary Algebra. It is essential, however, that this subject should grow naturally out of the Arithmetic and Mensuration, and it is perhaps to emphasize this aspect that the section in the *Handbook of Suggestions* which deals with Algebra is headed *Literal or Symbolic Arithmetic*. The same point of view is well expressed in the *Hadow Report,* where we read (following the advice to discard much of the traditional lumber of arithmetic) that—

> the omission of this work will make possible a freer treatment of arithmetic; the subject can be utilized to form a basis for other branches of mathematics which will be treated as logical developments of it. The pupil will come to view the subject of mathematics as a coherent system, the various parts acting and reacting on one another. The treatment consequently will not follow the usual academic lines. For example, algebra will be introduced naturally when, after suitable practical work on the area of a rectangle, the pupil generalizes his results, makes deductions, and employs symbols for the first time to express a formula. As his work in arithmetic and mensuration grows, so his formulæ become more complex; necessity arises for their transformation and manipulation, and out of this necessity the pupil learns how to solve an equation and how to transform his formulæ to make them easier to use; thus he is led to simple factorization, easy operations, algebraical fractions, and other developments. Indices are introduced as convenient abbreviations; their laws are thus readily observed and ultimately lead to logarithms, which most pupils come to regard as one of the really useful things which they learn in mathematics. It is desirable that the child should not be burdened with the academic work in algebra, such as is to be found in most textbooks on the subject. The really essential thing is that the pupil should have a clear understanding of the significance of formulæ, should be able to manipulate them, to solve equations arising out of them, and to use graphical methods intelligently.

It will be seen at once that the above extract summarizes, in convenient and handy form, the major possibilities of Algebra and algebraical methods in a good Senior School. It is important to note, in passing, the points which are emphasized in this extract, viz.—

1. The necessity for the approach through generalized statements, which arise naturally out of the arithmetic and mensuration.

2. The desirability of avoiding much of the meaningless manipulation of abstract symbols, which is to be found in a more academic course.

3. The importance of formulæ, their construction, interpretation, and exploration.

All these points are emphasized at greater length in the *Handbook of Suggestions* in the section on "Literal and Symbolic Arithmetic" already mentioned, and we shall accordingly develop the teaching of the subject along the general lines set out above.

Much attention has been devoted in recent years to the best methods to be followed in the early teaching of algebra, and many useful books and pamphlets have appeared for the guidance of teachers. Among these we may mention the following—

(*a*) *The Teaching of Algebra,* T. P. Nunn (Longmans); (*b*) *The Teaching of Elementary Algebra,* C. V. Durell (G. Bell & Sons); (*c*) *The Teaching of Elementary Algebra and Numerical Trigonometry* (published for the Mathematical Association by G. Bell & Sons); (*d*) "Algebraic Methods in Arithmetic," Chap. XXIII: *The Teaching of Arithmetic,* F. F. Potter (Sir Isaac Pitman & Sons, Ltd.).

Modern classbooks and textbooks owe much to some of the above books, particularly (*a*), and it may be said generally that the teaching of the subject, at least in Secondary Schools, has vastly improved during the past two or three decades. It remains only for teachers in Senior Schools to see that these modern methods and modern syllabuses are brought into constant use in the reorganized *Hadow* schools.

Algebra as Generalized Arithmetic

In making generalized arithmetic the natural and simple approach to algebra, teachers are to some extent following the historical development of the subject, for it may be remembered in this connection that Sir Isaac Newton described his own treatise on algebra as *Universal Arithmetic*, though it must be admitted that much of the very earliest algebra appears to have dealt largely with problems and equations. That process, however, which consists of generalizing from a series of similar arithmetical expressions, is without doubt the best for beginners, and is in accord with a widely-accepted maxim of teaching method, i.e. that teaching should proceed from particular to general. The steps in the approach are simple and almost invariably the same—the pupil examines a series of numerical instances, detects certain resemblances, and finally generalizes his deductions in a convenient "expression" or formula. It is a further step to interpret in particular instances any given formula, or to manipulate such a formula so as to make particular calculations easier.

It is unnecessary to emphasize to teachers that this transition from particular to general, from numerical instances to algebraic expressions, must be gradual and natural—

> Since the abstraction involved in the use of symbols presents difficulties to children, such work should be introduced gradually. To begin with, letters should only be substituted for numbers in types of sums that have been mastered, and the most suggestive letters should be selected, e.g. "s" for the number of shillings. The scholars may be trained to interpret and invent simple formulæ for expressing general statements. Many examples of what can be done can be given, e.g. if the daily wage of a man be S shillings, the pupil should see that the wages of M men for W weeks of 6 days each amount to $6SMW$ shillings or $\frac{6SMW}{20}$ pounds. Similarly formulæ to express areas of plane figures and volumes of solids can be discovered and applied. It must, however, be remembered also that the scholar will benefit more from the invention and interpretation of formulæ, than from their application, since the latter process may easily be and remain merely mechanical. (*Suggestions.*)

Now in this approach to algebra *via* arithmetic and mensuration, simple, natural, and logical though it is acknowledged to be, all practical teachers are fully aware that the major difficulties for beginners lie in the entirely new and strange *notation* which must be mastered. Ordinary algebraic notation is *not* easy for young pupils, and the meaning of literal symbols in combinations and expressions, together with the conventions employed for representing the simple operations such as addition, subtraction, multiplication, and division, must be patiently taught. No real progress is possible until the pupil can interpret such expressions as $a + b$ and $a - b$; until he realizes that $a + a$ and $2a$ are identical; until he recognizes that ab is the accepted shorthand for $a \times b$, and a^2, similarly, for $a \times a$. Until he is thoroughly familiar with such conventions, it is useless to expect him to give any intelligent meaning to the statement that the perimeter of a rectangle is given by $2\ (l + b)$, or that the simple interest on any sum of money is given by $\frac{PTR}{100}$.

It was formerly customary to teach this algebraic notation through a long series of exercises in "substitutions" of particular values for algebraic quantities. Thus former generations of pupils were introduced to algebra through the medium of innumerable exercises of the type: "Find the value of $2a^2 + 3ab + 4b^2$ when $a = 2$, and $b = 3$." Without doubt, such exercises, though otherwise meaningless, did assist in teaching the usual notation. But it is now recognized that notation can be taught equally well through the invention, interpretation, and use of formulæ in arithmetic and mensuration. Thus, a pupil who is thoroughly familiar with the general statement that the area of a circle is given by $A = \pi r^2$ (where πr^2 means $\pi \times r \times r$) will have no difficulty in interpreting the meaning of ab^2 or xy^2 or pq^2. Endless opportunities occur in arithmetic, in mensuration, and in elementary science for the invention and use of simple formulæ. Thus, in examples involving uniform motion, the speed is always given by the expression $\frac{D}{T}$. If any particular units are desired these may be specified, i.e. D and T must be expressed in miles and hours, or in feet and seconds, according as the speed is required in miles per hour or in feet per second. Further, many ordinary rules of life are capable of being reduced to simple formulæ. We illustrate with a few simple examples—

1. *Rule for Making Tea*

Allow one spoonful for each person and one extra for the pot.

Pupils may explore this numerically as follows—

1 person : 1 spoonful + 1 for the pot.
2 persons : 2 spoonfuls + 1 ,,
3 persons : 3 spoonfuls + 1 ,,

from which they will readily see that for n persons the number of spoonfuls is $(n + 1)$.

2. *Rule for Cooking Meat*

Allow 15 min. per lb. and 20 min. over.

Numerically, we have—

Weight of Joint	*Time of Cooking*
1 lb.	$15 + 20$ min.
2 ,,	$2 \cdot 15 + 20$,,
3 ,,	$3 \cdot 15 + 20$,,
etc., etc.	
or n lb.	$n \,.\, 15 + 20$,,

which is the formula required.

3. *Letter Postage*

Rate: 2 oz. 1½d., every additional 2 oz., ½d.

Numerically we have, taking the limits 2 oz. 4 oz., 6 oz., etc.—

	Weight	*Postage*
	2 oz.	1½d.
	4 oz.	1½d. + ½d.
	6 oz.	1½d. + 2·½d.
	8 oz.	1½d. + 3·½d.
whence	$2n$ oz.	1½d. + $(n-1)$½d.

4. *Spiral Spring (or Elastic Cord)*

Here the extension (within limits not to be discussed here) is directly proportional to the weight attached.

Suppose that the spring or cord is 1 ft. long and that every ounce added to it stretches it 1 in.

Weight Stretching Spring or Cord.	*Length when Stretched.*
0 oz.	12 in.
1 oz.	$(12 + 1)$ in.
2 oz.	$(12 + 2)$ in.
W oz.	$(12 + W)$ in.

Hence total length for a stretching weight of W oz. is $(12 + W)$ in.

It is a further step to generalize this for the case where a weight W stretches an original length a to a new length l. Here clearly $l = a + W \,.\, k$, where k is the amount of stretching produced by unit weight.

5. *Expenses of a Household*

These normally consist of two distinct parts: (a) a fixed overhead charge; (b) a variable amount for maintenance, which is mainly proportional to the number of persons resident in the house.

This may be expressed as follows—

$$\text{Total expenses} = C + n \,.\, P \text{ per week}$$

where C is a constant amount and P is the cost per person per week.

6. *Parcels Post*

This is rather harder to establish. The rule is: Up to 2 lb., 6d.; 2–5 lb., 9d.; 5–8 lb., 1s.; 8–11 lb. 1s. 3d. (limit).

Taking the limits at each stage, we have—

Up to 2 lb.	6d.
,, 5 lb.	6d. + 3d.
,, 8 lb.	6d. + 6d.
,, 11 lb.	6d. + 9d.

and the most convenient formula for this particular example is—

For a parcel not exceeding $(3n-1)$ lb., the postage is $(3n + 3)$d.; with the proviso that no value of n greater than 4 is allowed.

We have indicated above a few simple examples, and teachers should gradually amass for themselves a collection of suitable formulæ for exploration in this way.

Equally important is the exploration of formulæ which are supplied, ready for use, by the teacher. This is the opposite process from that described above, where the pupil proceeds from particular instances to a general statement. In this second method, the formula is supplied by the teacher, and its full meaning is explored by the pupils. Here everything will depend upon the kind of formulæ supplied. They must be simple, yet as varied as possible, and they must be real and practical. Science and mechanics will supply innumerable examples, while engineering science is a particularly fruitful field.

Changing the Subject of a Formula

In this use and exploration of formulæ, it is frequently necessary, for purposes of calculation, to transform a formula into a more convenient form. This has well been expressed as "changing the subject" of a formula. We may illustrate this by various examples.

1. *Arithmetic*

Distance travelled = Speed × Time

or $D = ST$

From this, by "changing the subject," we have

$$\text{(i) } S = \frac{D}{T} \text{ and (ii) } T = \frac{D}{S}$$

2. *Mensuration*

Area of a circle $(A) = \pi r^2$

whence $$r = \sqrt{\frac{A}{\pi}}$$

3. *Science*

(i) Time of swing of a pendulum $(T) = 2\pi\sqrt{\frac{l}{g}}$ where l = length of pendulum

From this we have

$$l = \frac{gT^2}{4\pi^2}$$

4. *Geography*

Distance of the visible horizon (D) at sea is $\sqrt{\frac{3}{2}h}$, where h is the height, in feet, of the observer above the sea-level.

from $D^2 = \frac{3}{2}h$

we have at once $h = \frac{2}{3}D^2$

Manipulations of this kind are essential in the interpretation and application of formulæ.

In conclusion we would urge teachers to make all possible use of the formula at this early stage. Let them encourage the pupils to invent simple formulæ, and to explore, interpret, and apply formulæ to particular cases, and they will find that much of the traditional and uninteresting work formerly associated with algebra for beginners may be avoided, with consequent gain to the average pupil, both in intelligence and adaptability.

From Formulæ to Identities and Equations

The transition from formulæ to identities and equations is not difficult. In effect, many identities *are* formulæ, and may be explored as such.

Of particular importance are those identities, such as $(a \pm b)^2 = a^2 \pm 2ab + b^2$, and $a^2 - b^2 = (a + b)(a - b)$, which are capable at once of geometrical demonstration and useful numerical application. Here the co-ordination of the different branches is complete, for the pupil may first perform the algebraic manipulations, then demonstrate the truth of the result by geometrical figures, and finally make use of the identity in suitable numerical calculations. Almost all expressions of the second degree are capable of this treatment. Thus the pupil may demonstrate, by drawing areas, that

$$a(b + c + d + e \ldots) = ab + ac + ad + ae \ldots$$

or that $(a + b)(c + d) = ac + ad + bc + bd$

identities which may be constantly employed in numerical calculations. In this connection it is a useful exercise for pupils to cast a calculation into the most convenient general form. As examples we may take the following—

1. *Find the area of the shaded figure in the diagram, from the measurements given.*

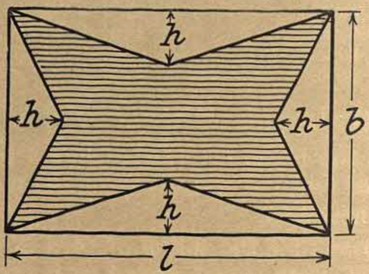


FIG. 1

Finding Area with Algebraic Symbols (1)

Here the containing rectangle has a length l and a breadth b, while the altitude of each triangle (not shaded) is h.

Now the shaded area is clearly the difference between the area of the containing rectangle and the four unshaded triangles.

Area of containing rectangle $= lb$.

Area of one larger triangle $= \frac{1}{2}lh$.

Area of one smaller triangle $= \frac{1}{2}bh$.

Hence Shaded Area $= lb - (lh + bh)$

or $lb - h(l + b)$

which is in a form suitable for easy calculation.

2. *Two quadrants overlap in a square, as shown in the diagram. Find the shaded area, from the measurement given.*

Here the area required is equal to the difference between the sum of the areas of the two quadrants and the area of the square.

Now the two quadrants together form a semicircle whose area is $\frac{\pi}{2}a^2$, and the area of the square is a^2. Hence the required area (shaded) is $\frac{\pi}{2}a^2 - a^2$ or $a^2\left(\frac{\pi}{2} - 1\right)$ or $\frac{4}{7}a^2$, which is in convenient form for calculation.

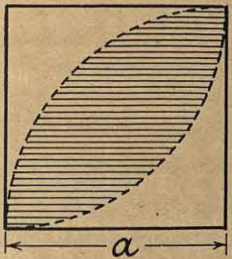


FIG. 2

Finding Area with Algebraic Symbols (2)

3. *Find the length of the perpendicular drawn from the right angle to the hypotenuse in any right-angled triangle.*

Let the sides of the right-angled triangle be a and b.

Let the distance required be x and the hypotenuse h. (Note that $h = \sqrt{a^2 + b^2}$.)

Now area of triangle $= \frac{1}{2}ab$

or $\frac{1}{2}xh$

hence $xh = ab$, from which we note that

$$x = \frac{ab}{h} \quad \text{or} \quad \frac{ab}{\sqrt{a^2 + b^2}}$$

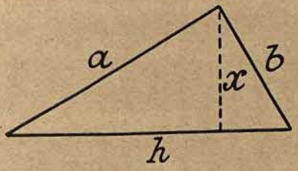


FIG. 3

To Find Length of Perpendicular from Right Angle to Hypotenuse

As a particular example we may take the right-angled triangle whose sides are 8, 15, and 17. Here $a = 8$, $b = 15$, and $h = 17$.

Hence the distance (x) required is $\frac{8 \times 15}{17}$ or $\frac{120}{17}$

$= 7\frac{1}{17}$

It is hoped that teachers, after studying the examples given above, will appreciate the beauty and simplicity of algebraic methods applied to calculations and will accordingly encourage their pupils, wherever possible, to cast their calculations into the most convenient algebraic form before performing the actual calculations.

Equations

When the difficulties of notation have been overcome, and formulæ can be manipulated and used with facility, most pupils readily grasp the principles involved in solving a simple equation. The difference between an identity and an equation has been very well expressed by Mr. C. V. Durell (*The Teaching of Algebra*, G. Bell & Sons) as the difference between thinking of the variable as (*a*) "some number, whatever you like," and (*b*) "some number, at present I don't know what." The process of finding the number in (*b*) is known as solving the equation.

The processes involved in dealing with the simple equation are neither numerous nor difficult. Many of them are identical with those involved in manipulating formulæ, especially in "changing the subject" of a formula. For beginners, the various manipulations may be summarized generally in the statement: "*If both sides of the equation are treated in the same way, then the equality is not altered.*" Furthermore, it may be noted that if several operations are thus performed on both sides of the equation, then the *order* in which such operations are performed does not affect the answer.

The following example illustrates all the ordinary operations—

$$3x - 2 = \frac{x}{2} + 8$$

(i) Multiply both sides by 2—

$$6x - 4 = x + 16$$

(ii) Add 4 to both sides—

$$6x = x + 20$$

(iii) Subtract x from both sides—

$$5x = 20$$

hence $x = 4$.

Usually, the process of adding or subtracting a number or quantity is performed by the artifice of transposing from one side to the other, at the same time changing the sign. All the operations are readily illustrated through the analogy of equal weights in each scale-pan of an ordinary balance.

Pupils readily learn to solve simple equations by applying the above operations, and teachers should accordingly beware of assuming that facility in solving equations is the same thing as facility in working *problems* by use of equations. In general, it is much more difficult for pupils to express problems in equational form, than to solve equations supplied by the textbook or teacher. It is thus necessary for the teacher to give constant practice in what is usually termed *symbolical expression,* in order to enable the pupil readily to form the necessary equation from the conditions of the problem. We illustrate with a few simple arithmetical problems which are easily solved by use of the simple equation.

The "Think of a Number" Type Examples[1]

(i) *What number added to* 15 *will give the answer* 23*?*

$$\text{Here} \quad N + 15 = 23$$
$$\text{whence} \quad N = 8$$

(ii) *What number subtracted from* 75 *will give the answer* 57*?*

$$\text{Here} \quad 75 - N = 57$$
$$\text{whence} \quad N = 18$$

(iii) *What number, divided by* 4, *will give the answer* 17, *with remainder* 3*?*

$$\text{Here} \quad \frac{N - 3}{4} = 17$$

(iv) *Ten years ago a boy's age was one-third of his present age. How old is he now?*

$$\text{Here} \quad x - 10 = \frac{x}{3}$$
$$\text{whence} \quad x = 15 \text{ years}$$

Unequal Division

(i) *Divide* 100 *into two parts, so that one part is* 16 *more than the other.*

Here the two parts are either $N - 16$ and N or $N + 16$ and N, according as N represents the larger or smaller number.

Taking the latter, we have, by addition—

$$2N + 16 = 100$$
$$\text{hence} \quad N = 42$$

and the two numbers are 58 and 42.

(ii) *Divide £1 among* 4 *boys so that one boy has* 4*s. more than each of the others.*

Here, let 3 boys have S shillings each, and 1 boy $(S + 4)$ shillings.

$$\text{Then} \quad 4S + 4 = 20$$
$$\text{and} \quad S = 4$$

Hence 3 boys have 4s. each and 1 has 8s.

(iii) *Divide* 105 *lb. into* 20 *parcels so that* 1 *parcel is twice as heavy as each of the others.*

Here, 19 parcels weigh P lb. each and 1 weighs $2P$ lb. Hence $21\ P = 105$ lb., which gives $P = 5$ lb.

Proportionate Division

(i) *Divide* 20 *into* 2 *parts in the ratio* 2 : 3.

Here, if the larger part is N, the smaller part is $\frac{2}{3}N$.

By addition, $\frac{5}{3}N = 20$, which gives $N = 12$, and the two parts required are 8 and 12.

Work, Pipes, etc.

(i) *One man does a piece of work in* 3 *days and another man in* 4 *days. How long should they take working together?*

Let $x =$ the time they take together.

In x days the first man does $\frac{x}{3}$ of the whole, and the second man does $\frac{x}{4}$ of the whole.

Hence $\frac{x}{3} + \frac{x}{4} = 1$ (representing the whole)

From this $x = 1\frac{5}{7}$ days.

(ii) *One pipe fills a tank in* 4 *min. and another empties it in* 6 *min. If both are open together how long will the tank take to fill?*

Using the same argument as in (i) above, we have

$$\frac{x}{4} - \frac{x}{6} = 1$$
$$\text{or} \quad x = 12 \text{ min.}$$

"CLOCK" SUMS

(i) *At what time between 3 and 4 o'clock are the hands of a clock together?*

Let the time required be x min. past 3.

A diagram will make it clear that

$$x = 15 + \frac{x}{12}$$

or $\frac{11}{12}x = 15$

hence $x = 16\frac{4}{11}$ min. past 3.

(ii) *At what time between 8 and 9 o'clock will the hands of a clock be opposite each other?*

Here a diagram will make it clear that—

$$x + 30 = 40 + \frac{x}{12}$$

From this—

$\frac{11}{12}x = 10$

and $x = 10\frac{10}{11}$ min. past 8.

The above indicate a few simple numerical applications of the principle of the Simple Equation. Many others will arise naturally in the course of the ordinary work in arithmetic. Additional examples will be found in any modern textbook of elementary algebra, but the wise teacher will not confine himself to textbook examples (which often contain some element of unreality). Rather, he will seek any and every opportunity for using the method of the equation in the solution of problems of every kind, as they arise in any branch of mathematics.

Problems Based on Geometry

The arithmetical problems indicated above, which are so readily solved by the use of the simple equation, have their counterpart in geometry, which is a wonderful source of interesting algebraic problems.

1. PROBLEMS BASED ON LINES

(*a*) *Find AC and CB where AC is 3 in. longer than CB.*

(*b*) *Find AC and CB, where AC is twice CB, etc., etc.*

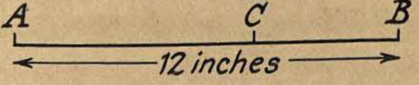


FIG. 4

To Find AC and CB where AC = 2 CB

$CB = x$ and $AC = 2x$, whence $3x = 12$

These may be extended to external points, e.g.—

Find AC′ and C′B, where AC′ is 1½ times C′B.

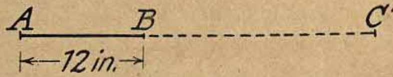


FIG. 5

To Find AC′ and C′B where AC′ is 1½ (C′B)

Here we may take BC' as x, and the simple equation to be solved is clearly

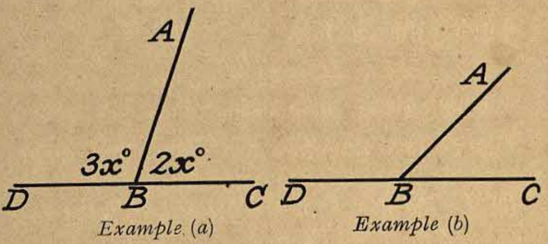
$$12 + x = \tfrac{3}{2}x$$

which gives x or $BC' = 24$ in.

2. PROBLEMS BASED ON LINES AND ANGLES

Examples.

(*a*) *In the diagram, find the size of each of the angles ABC and ABD.*



Example (*a*) *Example* (*b*)

FIG. 6

Exercises Based on Lines and Angles

Here the sum of the angles is 180°, hence the required equation is $5x = 180°$, from which $x = 36°$, and accordingly $ABC = 72°$ and $ABD = 108°$.

(*b*) *In the diagram, the angle ABD is thre times the angle ABC. Find the size of each angle.*

If the angles are $x°$ and $3x°$, we have $4x° = 180°$, which gives $x° = 45°$, and the two angles as 45° and 135°.

3. PROBLEMS BASED ON PARALLELS

Example.

In the diagram, find all the angles made by the line cutting the parallels.

Here $3x° = 180°$, which gives the angles as 60° and 120°.

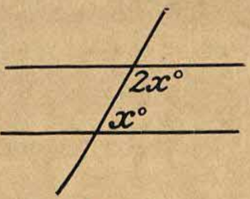


FIG. 7

Problem Based on Parallels

4. PROBLEMS BASED ON RECTANGLES

Examples.

(*a*) *In the diagram the perimeter of the rectangle is* 9 *ft. Find its length, width, and area.*

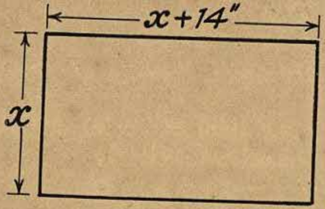


FIG. 8

Problem Based on Rectangle (*a*)

Working in inches, we have

$$\text{Perimeter} = 2\,(2x + 14) = 108 \text{ in.}$$

Solving this, we have

$$2x + 14 = 54 \text{ in.}$$

which gives $x = 20$ in.

Dimensions therefore are 34 in. and 20 in., from which the area can be found.

(*b*) *In the diagram, the perimeter of the rectangle is* 4 *ft. Find its area.*

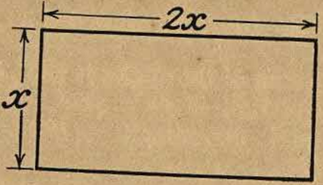


FIG. 9

Problem Based on Rectangle (*b*)

Working in inches, we have

$$\text{Perimeter} = 6x = 48 \text{ in.}$$

which gives $x = 8$ in.

and the area consequently is (8×16) or 128 sq. in.

4. PROBLEMS BASED ON TRIANGLES

(*a*) *The triangle ABC* (Fig. 10) *is right-angled at B. Find the size of the other two angles.*

Here clearly

$$5x^\circ = 90^\circ$$

which gives $x^\circ = 18^\circ$, and the angles as 36° and 54°.

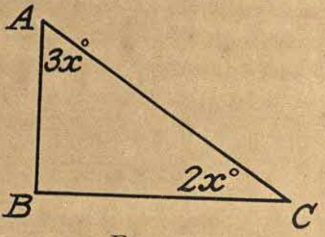


FIG. 10

To Find Unknown Angles in Right-angled Triangle

(*b*) *In the triangle DEF* (Fig. 11), *find the size of the two angles DEF and DFE, from the particulars given.*

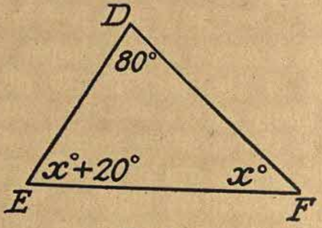


FIG. 11

To Find Sizes of Angles from given Data

Here $2x^\circ + 20^\circ = 180^\circ - 80^\circ = 100^\circ$ which gives 60° and 40° as the angles required.

(*c*) *GHK is an isosceles triangle* (Fig. 12). *Find the size of each of its angles, from the particulars given.*

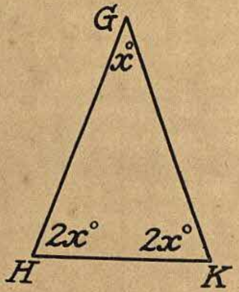


FIG. 12

To Find the Angles of given Isosceles Triangle

Here $5x^\circ = 180^\circ$, which gives x° as 36° and the angles of the triangle as 72°, 72°, and 32°.

These problems, involving both geometry and algebra, should be constantly employed by the teacher, and in this way arithmetic, algebra, and geometry will be connected and correlated in the most useful way.

Additional Work in Algebra

Older pupils will find fascinating work in exploring certain of the regular series of numbers. Thus they will soon develop for themselves a method for summing any arithmetical series, on the basis of the following formula—

Sum of a Series = No. of terms × Average value of each term.

or $S = N \cdot A$

Now A is readily found (by writing the series in the reverse order) to be half the sum of first and last terms, hence $S = N\left(\frac{f+l}{2}\right)$.

Example.

Find the sum of 1, 4, 7, 10, 13, 16, 19

Average $= \frac{1}{2}(1 + 19) = 10$

Hence sum $= 7 \times 10 = 70$.

The series of odd numbers is of especial interest.

It will be noted that the sum of any sequence of these is a perfect square, e.g.—

$$\begin{aligned}
1 + 3 &= 4 = 2^2\\
1 + 3 + 5 &= 9 = 3^2\\
1 + 3 + 5 + 7 &= 16 = 4^2\\
1 + 3 + 5 + 7 + 9 &= 25 = 5^2\\
1 + 3 + 5 + 7 + 9 + 11 &= 36 = 6^2
\end{aligned}$$

from which we may deduce that the sum of n such numbers must always be n^2.

This interesting result may be readily demonstrated graphically on squared paper as follows—

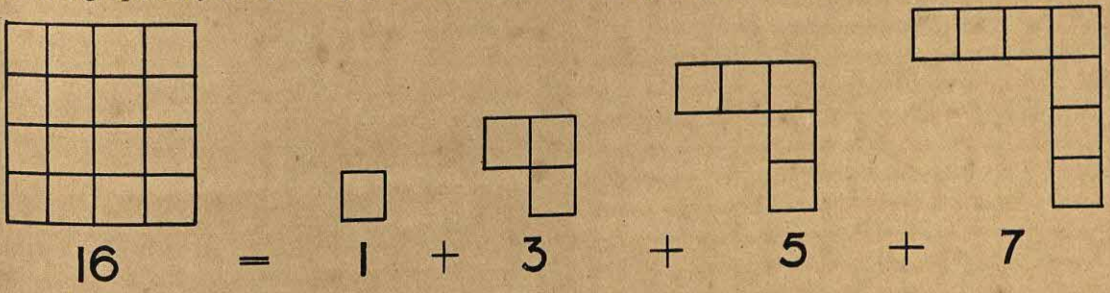


FIG. 13

Graphical Demonstration: Sum of n Odd Numbers $= n^2$

The diagram shows how any square (e.g. 4^2) may be divided into a series of gnomons representing the odd numbers.

Again, pupils who are interested may explore these odd numbers still further, and note that they may be grouped so as to give *cube* numbers, as follows—

$$\underset{1^3}{1} \qquad \underbrace{3 \quad 5}_{2^3} \qquad \underbrace{7 \quad 9 \quad 11}_{3^3} \qquad \underbrace{13 \quad 15 \quad 17 \quad 19}_{4^3}$$

FIG. 14

Cubic Grouping of Odd Numbers

These same cubes may also be discovered in the products of the multiplication table arranged in a square, as in the diagram, where each gnomon as indicated will be found to contain a perfect cube. (*Example* $3 + 6 + 9 + 6 + 3 = 3^3$.)

1	2	3	4	5
2	4	6	8	10
3	6	9	12	15
4	8	12	16	20
5	10	15	20	25

FIG. 15

Gnomon Grouping of Odd Numbers

Conclusion

What we have indicated above may be taken in general to be the most important part of the algebra syllabus in the ordinary Senior School. We have emphasized as the main points—

1. Notation and simple manipulations.
2. Formulæ—their discovery, interpretation, and use.
3. Simple equations and problems solved by such equations.

MODERN DEVELOPMENTS

THE USE OF GRAPHS

(*a*) The drawing of graphs is now a very general exercise in schools. These geometrical illustrations are of two kinds. In the first place, there are the charts which form a convenient means of recording quantities which fluctuate in an irregular way, e.g. the attendance of the school, or the temperature of the classroom, or the price of eggs at different times of the year. In the second place there are the graphs which express in a diagrammatical form the relation between two connected quantities. Thus it is easy to construct a diagram which may be used as a ready-reckoner, e.g. one which will give the square or square root of any number within a given range, or the relation between the side and area of similar triangles, or the relation between "cost price" and "selling price" for any particular percentage of profit.

(*b*) It must always be borne in mind that the interpretation and use of graphs are as important as their construction. Thus pupils will be led to see that in addition to the ready picture they give of a sequence of events, they are of importance in giving, by interpolation, information not afforded by the data or information as to the rate of increase of a varying quantity (e.g. in a graph showing the distance a train has gone at different times, the greater the speed of the train, the greater will be the slope of the graph).

THE above extracts from the *Handbook of Suggestions* are a fitting introduction to this discussion on the place of graphs in the Senior School.

We shall therefore proceed to develop the ideas, expressed above, in some detail.

Graphs of all kinds have achieved their present position in schools only by a somewhat slow process. The older teacher is inclined to look askance at "graphs," since they take so much more time to construct than "sums" take to "work" and, further, where they are used to *solve* arithmetical problems, the required solutions are generally more obvious, and frequently more accurate, when obtained by the older method of "sums." But, gradually, teachers have realized that graphs are an invaluable aid in both arithmetic and algebra. Philosophically, the argument is all in favour of graphs as against "sums." The ordinary "problem" in arithmetic presents merely an isolated static view of one infinitesimal portion of a whole world full of variables, dependent and independent, and this world of flux, capable of being reduced to some sort of order through mathematics, is vividly represented to young pupils through the medium of graphic methods wisely used. To quote from the writer's own *Teaching of Arithmetic* (Sir Isaac Pitman & Sons)—

> No longer shall we in our mathematics amuse ourselves, after the fashion of the schoolmen of the Middle Ages, in propounding to one another ingenious little problems and puzzles for arithmetic or algebraic solution. Rather, shall we view the universe as a unity amid all its diversity; where phenomena are analysed into their interdependent elements; where change is ceaseless yet orderly; where rise and fall, increase and decrease, growth and decay, eternally proceed. We may (and indeed we *must* under the limitations of our intellect) make mentally a cross-section of this never-ceasing stream of change, and thus secure a sufficiency of data to concoct our sums, but this static view is largely an illusion for, even as we work our example, the reality it seeks to represent is changing; and the ultimate value of mathematics is this: that in it we have man's attempt to reduce this eternal flux of things to order and law within the measure of his intelligence and the means of his expression. Only from this dynamical view of the universe can the meaning of function and functional variation be grasped, and this idea of functionality is the only sound foundation for the teaching of graphs.

The transition from the formula to the graph is easy and natural, for they are both but different aspects of the same truth. Each, in its own way, expresses the relation between a number of connected facts, and each is a mode of expression compact and convenient to the properly tuned intellect—the formula appealing more to the inward eye, and the graph arresting the very eye itself. The formula is more compact and the graph more vivid, but each illuminates and complements the other.

Discontinuous and Continuous Graphs

The first extract quoted above indicates a useful division of graphs for beginners into two main classes: (*a*) graphs of irregular fluctuations, or discontinuous graphs; (*b*) graphs of quantities related according to some simple or complex formula—these are usually known as continuous graphs. The distinction is convenient and useful. Graphs of the former kind are frequently termed statistical or picture graphs, while the latter may be termed algebraic or functional graphs. One of the fundamental differences between the two classes of graphs is that, with the former, the process known as interpolation, or the deducing of other values intermediate to those given, is generally impossible, whereas in the true functional graph, values are continuous with the curve itself, and may be deduced at any desired point.

Picture Graphs

Discontinuous graphs, or picture graphs, undoubtedly form the best starting point for beginners. Ample material is always ready to hand: attendances of school or class; marks obtained in various school subjects; daily temperatures (at a given time of day); average monthly temperatures; barometric readings and variations; rainfall; "lighting-up" times; "tide" times; hours of sunshine; indeed, all the ordinary phenomena of the physical world may be graphically recorded. The work is not difficult; the disconnected quantities are usually represented by a series of vertical lines or rectangles drawn to the same scale, and spaced at equal horizontal intervals. The term "ordinate" may be introduced at this stage, but is not really necessary. The graphs, when drawn, show striking *pictures* of certain facts, and should be *used*, when drawn, as indicated below, for oral discussion and deduction where possible.

From such definitely discontinuous graphs we may pass in easy stages to graphs of quantities which obviously follow some kind of law, even though this law may be hardly capable of being reduced to a simple formula. Particular examples of this kind are graphs illustrating the average heights or the weights of children and adolescents at different ages. These curves, though hardly "regular" in the strict mathematical sense, are, nevertheless, orderly and continuous, and interpolation is possible with fair accuracy. Of a similar kind are graphs showing the times of sunrise or sunset at a certain place on different days of a month. Here, again, *order* will be noted, even if no *formula* is possible.

A course in graphs for beginners, then, will include a series of exercises in illustrative or picture graphs as indicated above. The second extract from the *Suggestions*, quoted above, indicates an equally important aspect of graphical work for the teacher: *"It must always be borne in mind that the interpretation and use of graphs are as important as their construction."* This point of view is sometimes overlooked by the teacher who *begins* his graphical work with the actual *drawing* of graphs. Much time is frequently thus absorbed in overcoming the ordinary difficulties of working in a new medium, and, in consequence, many teachers are now experimenting by beginning with the *interpretation* of graphs already made. For this purpose a series of well-drawn printed graphs is required. If the teacher has a supply of these, many useful oral lessons in the interpretation of graphs may be given before the actual task of drawing graphs is attempted. Suitable graphs for this purpose, drawn to a convenient size and capable of being seen by all members of a class, may be prepared by the teacher, or smaller graphs thus prepared may be duplicated, and copies supplied to each member of the class. The pupil is then questioned on the meaning of the graph, and is asked to make a series of deductions from it. We recommend this preliminary discussion and interpretation of previously-prepared graphs as a most valuable introduction to the actual drawing of graphs (see P.S.T. Graph Chart).

The Drawing of Graphs

Much preliminary investigation must be carried out by the pupil before the actual drawing of a graph is begun, and among the most important matters requiring decision is that of the scale to be used, for upon this scale frequently depends the whole practical value of the graph when completed.

Some teachers prefer to begin by using *plain* paper, rather than *squared* paper, and it is certain that the use of plain paper for a few examples at the outset does concentrate the attention of the pupil upon the importance of the scale and the necessity for accuracy of drawing.

It will further enable him to appreciate the valuable assistance which squared paper gives in the drawing of any graph. In general, however, except at the outset, squared paper will be in regular use.

In the actual drawing it must be emphasized to the pupil that the value of the graph when drawn depends upon its instantaneous appeal to the *eye* of the observer—it must as far as possible be self-evident. For this purpose we venture to repeat certain "rules" which have already appeared in the writer's *Teaching of Arithmetic*—

1. The units chosen should be as large as the paper will allow. This involves a careful choice of scales, and the same scale for both vertical and horizontal quantities is seldom possible.
2. Each axis should be carefully numbered and named. If the numbering is plainly shown, it is unnecessary to add such statements as "Scale—1 square = (   )."
3. Points on a graph should be indicated by some simple convention, preferably by a ×.
4. The graph, when completed, should be given a brief explanatory title, such as "Graph of ——" or "Graph showing the connection between —— and ——."

As soon as the pupil has mastered the initial difficulties of "plotting" on squared paper, he should be able to make rapid progress in the drawing of graphs, regular as well as irregular.

Continuous Curves

Foremost among these are the "straight-line" graphs which illustrate all cases of simple direct proportion. Thus we may readily teach our pupils to draw such graphs as those which illustrate the price of eggs at 1s. 6d. per dozen, or of cakes at 5 for 3d., and similarly for any quantities which vary together at a fixed regular rate. All these graphs will take the form of straight-line graphs, and, when drawn, may be interpreted, explored, and used by the class as much as is considered desirable by the teacher.

Of a similar kind are Simple Interest graphs, showing the relation between the interest and the time for a given rate of interest, and percentage graphs, indicating a given percentage of varying sums of money, or the relation between marked price and cash price at a given rate of discount. Particularly valuable as ready reckoners are those graphs which may be termed *conversion* graphs, especially those which show the relation between English and metric units. As an example, we may take *litres* and *pints*.

The basic relation is 1 litre = 1·76 pints. This may be transformed to 100 litres = 176 pints, or 25 litres = 44 pints. Either of the latter may be used as the basis for the straight-line graph or ready reckoner, according as it is desired to convert to litres any number of pints up to 44 pints or up to 176 pints.

As examples of the type of work just indicated we give an exercise taken from *Common Sense Arithmetic for Senior Boys*, Book II.

(1) (*a*) If 1 kg. is equal to 2·2 lb., express 100 kg. in lb.
  (*b*) Using the relation just found in (*a*), draw a straight-line graph to change kilograms to lb. and *vice versa*.
  (*c*) Read off from the graph the value of 1 cwt in kg., and of 40 kg. in lb.
(2) (*a*) Given that 1 in. is equal to 2·54 cm., draw a graph to change inches to centimetres and *vice versa*.
  (*b*) Use this graph as directed by your teacher.
(3) Given that 1 litre is equal to 1·76 pints, draw a graph to change litres to pints, and use the graph as directed by your teacher.
(4) Given that 1 kilometre = ·62 mile, draw a graph to change kilometres to miles, and use the graph as directed by your teacher.
(5) Consult a daily newspaper to find the exchange rates per £1 between Great Britain and (*a*) France, (*b*) Germany, (*c*) U.S.A.
  Then draw three separate graphs, changing (*a*) francs, (*b*) marks, (*c*) dollars to £.
(6) Taking £1 as equal to 100%, draw, on a good scale, a graph to express all sums of money up to £1, as percentages of £1.
(7) Taking 1 ton as equal to 100%, draw, on a good scale, a graph to express all weights up to 1 ton, as percentages of 1 ton.
(8) A dealer marks all goods at 15% above cost price. Draw a graph showing the relation between marked prices and cost prices, starting with the fact that £100 cost price becomes a marked price of £115.
(9) At a sale all goods are reduced by 3s. in the £. Draw a graph giving the sale price of all articles up to £20, starting with the fact that a price of 20s. becomes a sale price of 17s.
(10) Draw a graph, giving the interest for one year on all sums of money up to £1,000 at 5% per annum, starting with the fact that £100 gains £5.
(11) Draw a graph, showing the amount in one year of all sums of money up to £1,000 put out at interest at 6%, starting with the fact that £100 amounts to £106.

Time-and-Distance Graphs

These are important and interesting, and the data will result in straight-line graphs only if the speed is uniform and continuous. It is possible to illustrate with graphs of this character the solutions to those time-honoured problems such as men or trams passing or overtaking one another; men performing a "piece of work"; taps or pipes filling bowls or tanks; and even "clock" sums; but work of this kind may easily be overdone, and the solutions thus obtained may usually be more readily obtained by arithmetical or algebraic methods.

Other Regular Curves

Pupils should receive practice in the drawing of the simple rectangular hyperbola from data obtained by the numerical exploration of some simple case of inverse proportion.

Example.

Two numbers multiply together to give 72 as the product. Find all the possible pairs of factors and show these on a graph.

Pairs of Factors	1	2	3	4	6	8
	72	36	24	18	12	9

These if plotted on squared paper will give one-half of the curve known as the rectangular hyperbola.

Pupils should also receive ample practice in plotting the parabola or simple curve of squares. Numerous instances of this curve are available, e.g.—

(i) Areas of similar triangles having different bases.

(ii) Areas of circles having different radii.

(iii) Areas of squares having different sides.

(iv) Distance and time of bodies falling freely from rest.

(v) Time and length for a simple pendulum, and many other examples drawn from mechanics and physics.

If the above work is systematically carried out, pupils will have a very clear and real understanding of the idea of proportionality, and the best of them may attempt to reverse the process, and to deduce the "law" or "formula" from the curve obtained as the result of plotting the given data. In the words of the *Suggestions*—

> It will soon be seen that any question of a given type has its typical graph, for example a straight line in the case of a question involving direct proportion. Conversely, the graph may be used to suggest the law connecting the quantities plotted. Thus graphs plotted in elementary science lessons connecting effort with weight in a system of pulleys, or the extension of a spring with the attached weight, should lead pupils to suspect a direct proportionality in those cases, and the next step will be to write down the formula showing the proportionality, the constant factors having been ascertained from a graph.

The Graph of a Function

So far we have not spoken directly of graphs as representing functions, but it is possible to explore this aspect of the subject with the best of the older pupils, especially those who are remaining at school beyond the age of fourteen.

This is indicated in the concluding paragraph of the section on Graphs in the *Handbook of Suggestions*, which is as follows—

> In some cases it will be found possible to link up the graph work to a greater or less extent with algebra. Thus it will be learnt that a particular problem may be solved arithmetically or by simultaneous equations or graphically and that a graph of two straight lines can be used for the solution of simultaneous equations. It will come to be recognized in this kind of way that an expression of the first degree in x is represented in a graph by a straight line, and that a quadratic expression is represented by another typical graph.

Further, in that section of the *Handbook of Suggestions* which deals particularly with mathematics in Central and Senior Schools, we read—

> The pupils may be shown that the rate of increase and maximum and minimum values of an expression can be found from the graph, and they may use graphs for finding approximately the roots of equations which cannot readily be solved by algebraic means. In some schools the most advanced pupils may deal with the graph of a function as an introduction to the calculus which they may have occasion to learn later.

It is not to be assumed from the above that the teacher is to introduce generally the graphs of algebraic functions. This work soon becomes beyond the scope of the average Senior School pupil. An even worse mistake for teachers is to attempt to teach that particular branch of mathematics known as "co-ordinate geometry." Yet certain simple aspects of these subjects can, and should, be introduced. Thus it is *not* difficult to teach the best of the Senior boys that the expression $y = ax + b$, if plotted on square paper, does actually result in a straight line. This may be explored experimentally by plotting a series of lines such as $y = x$, $y = 2x$, $y = 3x$, $y = \frac{1}{2}x$, $y = \frac{1}{3}x$, etc., and pupils rapidly grasp the principle that the value of "a" or the coefficient of x, in $y = ax + b$ determines the slope or gradient of the graph. Similar exercises for a series of values of "b," i.e. $y = x$, $y = x + 1$, $y = x + 2$, $y = x + 3$, will result in a series of parallel lines which indicate that "b" is always the intercept on the axis of y.

The quadratic curve may be similarly explored. Thus, the pupils may plot a series of parabolas: $y = x^2$, $y = 2x^2$, $y = 3x^2$, etc., and in this way they will discover the influence of the coefficient of x^2 upon the steepness or gradient of the graph. From this they may proceed to such graphs as those of $y = x^2 + x$, $y = x^2 - x$, and ultimately to the general form—$y = x^2 + ax + b$.

When the above curves have been fully explored the solution of algebraic equations by graphic means is not difficult, and pupils readily grasp the solution of simultaneous graphs by the process of noting where certain lines or curves intersect, while maximum or minimum values of a quadratic curve are easily deduced from a properly drawn graph.

Conclusion

We have, we think, indicated fully the possibility of graphic methods in Senior Schools. The work is at once interesting and useful, suitable alike for boys and girls, and a mastery of the method will be of the utmost assistance not only in mathematics but also in other subjects, particularly geography and science.

LOGARITHMS

The advice given in the *Handbook of Suggestions* on the question of the teaching of logarithms in Senior Schools is clear and definite.

> There is no reason why logarithms should not be taught to boys at about the age of 13 years, even in ordinary Elementary Schools. The facility which is soon gained in the use of tables will be of value to those who continue their education in Evening Technical Schools. The saving of time involved in dealing with long mensuration calculations enables more of such calculations based on actual measurements to be undertaken. Before the use of the tables is taught pupils should be familiarized with the use of indices, which in the case of positive whole numbers should be introduced at first merely as a convenient notation. The teacher should elucidate the various steps in the use of the tables by simple reasoning; he need not attempt to give any formal proof.

Every teacher who has had experience in teaching boys from 13 or 14 onward knows very well that boys of this age readily learn to use logarithms, and that they are in no way inconvenienced if all reference to the underlying theory is entirely omitted. But the rules controlling the use of logarithms are not difficult to explain or to justify. As indicated above, the manipulation of logarithms to the base 10 is only a series of particular applications of the universal laws of indices. We illustrate by comparative statements—

Indices	*Logarithms*
(1) $a^m \times a^n = a^{m+n}$	$\text{Log}\,(xy) = \log x + \log y$
(2) $a^m \div a^n = a^{m-n}$	$\text{Log}\left(\frac{x}{y}\right) = \log x - \log y$
(3) $(a^m)^n = a^{mn}$	$\text{Log}\,(x)^y = y \log x$

From these, the ordinary rules for using logarithms are evolved.

The main difficulty in using Common Logarithms lies in the meaning and manipulation of "characteristics," especially negative characteristics. Thus the pupil who is aware that log 3 is ·4771 must be led to realize that $3 = 10^{\cdot 4771}$, and from this he may be led to reason that log (·3) is the same as log $(\frac{3}{10})$ or log 3 − log 10, i.e., ·4771 − 1, which is conventionally written $\bar{1}\cdot4771$.

The manipulation of negative characteristics must also be practised. Addition, subtraction, and multiplication of these seldom give much trouble, but the process of dividing such a quantity as $\bar{1}\cdot4771$ is more difficult at the outset and must be carefully practised.

Graphic Logarithms

Much interesting light is thrown upon logarithms and their connection, if a few logarithmic curves are drawn. The simplest case is the curve showing the relation between the natural numbers and their logarithms to the base 10, which should be drawn to a good scale on squared paper. Finally, if these Common Logarithms are plotted along a strip of paper to represent one scale of a slide rule, and a similar strip is plotted to represent the movable part, the whole basis of the construction and use of the ordinary slide rule becomes readily apparent.

Logarithms, when dealt with carefully by an enthusiastic teacher, will readily appeal to boys. In them they will realize that they possess a very valuable calculating instrument, shortening labour, and giving results which are generally approximately accurate.

In the choice of *Tables*, it will generally be found sufficient if tables of four or five figures are employed.

NUMERICAL TRIGONOMETRY

> All "selective" schools keeping pupils beyond the age of 14 may well teach the simple trigonometrical ratios, and the use of tables to solve height and distance problems involving right-angled triangles, while some may proceed to the trigonometrical solution of any triangle. It will, however, as a rule, be sufficient to teach the "sine rule," and the cosine formula for the solution of any triangle, given its three sides: all other cases may be solved by dividing the triangle into two right-angled triangles.
>
> (*Suggestions.*)

Numerical trigonometry, involving the use of tables to four or five figures, is not difficult to teach or to learn, and the following simple development is suggested to those teachers who have not yet tried the experiment.

First Stages

THE FUNDAMENTAL RATIOS

These are, of course, based upon similar right-angled triangles.

The first ratio, i.e. sine, or $\frac{\text{opposite side}}{\text{hypotenuse}}$ should be experimentally explored for a series of similar right-angled triangles, as in Fig. 1.

The pupil should verify, by actual drawing and measurement, that the successive ratios $\frac{AB}{OB}$, $\frac{A_1B_1}{OB_1}$, $\frac{A_2B_2}{OB_2}$, etc., are constant in value, and he should learn by heart that this constant ratio, $\frac{\text{opposite side}}{\text{hypotenuse}}$, is called the *sine* of the angle BOA.

The other two fundamental ratios, the cosine and the tangent, should be similarly treated. Practice may then be given in reading off the values of these ratios in a series of right-angled triangles whose sides are known (see the Theorem of Pythagoras).

Examples are as given below (Fig. 2).

Here, for instance, sine $ABC = \frac{3}{5}$, cosine $DEF = \frac{12}{13}$, and tangent $HKL = \frac{8}{15}$, and so on. These ratios may be reduced to decimals, and the actual size of the angles approximately determined by reference to trigonometrical tables.

Example.

Sine $ABC = \cdot 6 =$ sine 36° 48′ approx. (from tables).

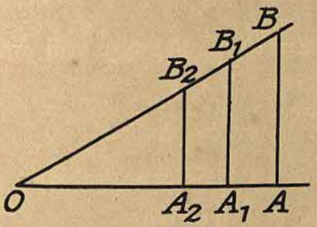


FIG. 1

Exploring the Fundamental Ratio "Sine"

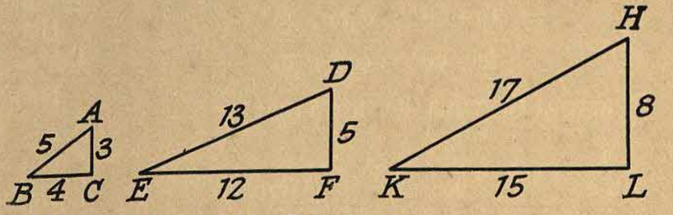


FIG. 2

Exercises in the Fundamental Ratios

To Find Graphically the Value of the Trigonometrical Ratios for any Given Angle

This is the next convenient stage for a beginner. Careful drawing and measurement will yield an approximate value for all the three fundamental ratios.

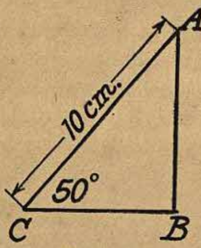


FIG. 3

To Find Graphically Sine 50°

Example.

Find graphically sine 50°.

The angle 50° is first carefully drawn by means of the protractor. This angle is then made one angle of a convenient right-angled triangle. (In this case it is useful to make the hypotenuse 10 cm. long, as indicated in the diagram).

$$\text{Then sine } ACB \text{ or sine } 50° = \frac{AB \text{ (in cm.)}}{10},$$

which enables an approximate value to be found to two decimal places, if AB is measured to the nearest millimetre.

Trigonometrical Tables

After the above experimental methods have been employed, the pupil is in a position to learn to read and use the ordinary trigonometrical tables, which give the value of the fundamental ratio correct at least to four decimal places.

At the same time, the pupil will learn a fact which has probably been noticed already, viz. that any ratio of an angle is the co-ratio of its complement, e.g.—

$$\text{Sine } 60° = \text{cosine } 30°$$

$$\text{Tan } 60° = \text{cotan } 30°$$

$$\text{Sec } 60° = \text{cosec } 30°$$

He may at the same time learn that

$$\frac{1}{\tan} = \text{cotan}, \quad \frac{1}{\cos} = \text{sec, and } \frac{1}{\text{sine}} = \text{cosec},$$

but these new identities are not essential at this stage and may be omitted if they confuse beginners.

Easy Problems

As soon as the pupil has mastered the meaning of the fundamental ratios, and can read them from a diagram, or obtain their numerical values from a table, he is in a position to apply his knowledge to easy problems, and these may be invented in copious variety.

These earliest problems should all be based upon a simple right-angled triangle.

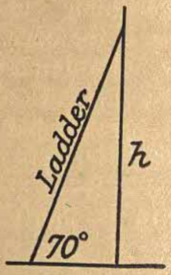


FIG. 4

Construction for Ladder Problem

Example.

A ladder 20 *ft. long stands as in the diagram. Find the height of the top of the ladder above the ground.* (See Fig. 4.)

Here, let h be the height required.

$$\text{Then } \frac{h}{20} = \text{sine } 70° \qquad = \cdot 9397 \text{ (from table)}$$

$$\text{Hence } h = 20 \times \cdot 9397 = 18 \cdot 794 \text{ ft.}$$

$$= 18 \text{ ft. } 9\tfrac{1}{2} \text{ in. nearly.}$$

Problems of this kind may easily be invented by the teacher to give practice in all the ratios, and they are usually most attractive to young pupils.

Special Triangles, e.g. Equilateral and Isosceles

If the pupil is fully alive to the fact that the altitude of an equilateral or isosceles triangle always bisects the base, then numerous problems based on these special triangles are possible.

Example.

Find the height of an equilateral triangle of side 10 cm.

Here reference to a diagram will indicate that—

$$\frac{\text{Height required}}{10 \text{ cm.}} = \text{sine } 60°$$

$$= \cdot 866 \text{ (from table)}$$

$$\text{Hence height} = 8 \cdot 66 \text{ cm.}$$

Similar methods will solve problems of the following type—

(*a*) *In an isosceles triangle, the base angles are* *each* 40° *and the equal sides are each* 10 *in long. Find the base and height of the triangle.*

(*b*) *In an isosceles triangle, the base is* 6 *in., and the sides are each* 8 *in. long. Find the base angles.*

(*c*) *In an isosceles triangle, the base is* 10 *in., and the base angles are each* 42°. *Find the length of each of the equal sides, and the height of the triangle.*

Some teachers insist that their pupils shall memorize the values of the ratios of common angles such as 60°, 45°, and 30°, but if the use of tables is fully understood this memorizing is not necessary.

Heights and Distances

From simple triangles, the transition to "heights and distances" (all based upon a single right-angled triangle) is not difficult, and the teacher should be prepared with varied examples for class use, involving, if possible, only a single angle.

Harder examples involving the use of various angles and triangles should be reserved for a later stage.

Graphs of Trigonometrical Functions

At this stage, when the pupil is familiar with the meaning and use of the fundamental ratio, he may, as an exercise, draw the graphs of sin x, or cos x, or tan x as x increases from 0° to 90°. Though these curves are hardly of much practical use at this stage, the exercise of actually drawing them is not without interest and value.

Harder Developments in Trigonometry for Advanced Pupils

When the elementary stages, indicated above, have been passed, it is possible to extend numerical trigonometry in several useful directions as follows—

1. Logarithmic solution of right-angled triangles (this will involve the use of logarithmic sines, cosines, and tangents).
2. Logarithmic solution of isosceles triangles.
3. The ratios of angles greater than 90°.
4. Applications to triangles generally of the "sine rule" and the "cosine" formula.
5. Harder problems in heights and distances.
6. Numerical problems in "solids" (or in three dimensions).
7. Application of the trigonometrical ratios to miscellaneous problems in mensuration and geometry.

THE ULTIMATE GOAL OF SENIOR SCHOOL MATHEMATICS

IN the foregoing sections we have indicated the possibilities of Mathematics in the Senior School both for boys and for girls. We are fully aware that we have outlined more than sufficient for any single syllabus, and we would wish our readers clearly to understand that we do not desire or hope to see all the numerous topics which we have dealt with fully developed in *all* schools. We shall indicate, later, some possible syllabuses both for Boys' Schools and for Girls' Schools, but at the moment we wish to draw attention to the special needs of those boys who will proceed to Part-time Evening Instruction in Technical Subjects.

Boys' Technical Training

Fortunately, this is a branch of Technical Education which, in the more industrial parts of the country, is very highly and very efficiently organized, and we cannot do better, therefore, than examine in some detail the work in mathematics which is thought to be necessary for these part-time evening students who desire to enter upon a Senior Technical Course at the age of 16.

As a convenient instance, we may examine the courses outlined by the Examinations Committee of the well-known Union of Lancashire and Cheshire Institutes.

This Preparatory Senior Technical Course is arranged for two years' work, and in each year Practical Mathematics and Practical Drawing occupy the most prominent place. We quote from the "Prefatory Notes"—

(*a*) The Preparatory Senior Technical Course consists of two stages—First Year and Second Year. The First Year is intended for all students who will ultimately proceed to a senior technical course, major or minor. The Second Year is intended only for those students who will proceed to a senior major course. The "major" courses include the National Certificate courses in Mechanical Engineering, Electrical Engineering, Naval Architecture, Chemistry, and Building, and the courses in Coal Mining, Cotton Spinning, and Cotton Weaving; the "minor" courses are the "trade" and "workshop" courses.

(*b*) The First Year is intended for boys who leave school at 14 *plus*. The instruction is expected to cover 22–24 weeks.

(*c*) The Second Year is intended for boys who have passed the First Year, or who have remained at school until they are 15 *plus*. The instruction is expected to cover 28 weeks.

(*d*) The normal age of admission to a senior technical course is 16 *plus*. It is hoped, therefore, that exemptions from either year of the course in respect of students of normal age will be given sparingly. If this is not observed, students will gain admission to senior courses while they are still too young to profit from the instruction.

The Syllabuses (with the prefatory remarks) are as follows—

PRACTICAL MATHEMATICS

(*a*) As the classes in the First Year of the course will contain students who will proceed to major and minor senior courses, the syllabus for this stage has been limited to simple arithmetic and mensuration and algebra. The fundamental ideas with which technical students are concerned are length, direction, area, volume, and weight, and mensuration forms the main body of the syllabus. The addition of time to the other dimensions enables other problems of practical interest and utility to be introduced.

(*b*) The work in mensuration should often be based upon the students' own drawings and measurements of actual objects. For this purpose each student should be provided with a 12-in. rule graduated in inches and also in centimetres, T-square, set-squares, protractor, compasses, and calipers, and there should be a supply of simple geometrical models and objects for each class.

(*c*) Though the requirements in algebra are indicated in a separate paragraph, it is assumed that this subject will be taught and applied side by side with arithmetic throughout the session. Ample practice in the manipulation of symbols should be given and it will be found profitable to devote a portion of each lesson to "drill" in those processes, arithmetical and algebraical, in which a good deal of repetition is required to attain speed and accuracy.

(*d*) As the classes in the Second Year of the course will contain only students who will proceed to a major senior course, the syllabus for this stage is wider in scope and implies a higher standard. It consists broadly of three sections—an extension of algebra, indices, and the use of logarithms; length and direction treated by the method of scale drawing, and then, in a more general way, by simple trigonometry; and variation, treated first particularly and then generally by the equation to a straight line. Equations to curved lines are not required, but the teacher may find it desirable to show the graphs of other equations in order to emphasize the form of the straight line equation. The students will become familiar with the graphs for Boyle's and Charles's Laws in the science for the same year. Time may be saved and revision by mere repetition avoided by so choosing the examples set throughout the session that methods and processes learnt in the earlier weeks are frequently employed afterwards. Weekly "drill" in processes which require much practice will also be found useful.

(*e*) In both years, the examinations will include only those rules and topics which are of real importance to technical students. A knowledge of British weights and measures which are not in common use will not be required. Problems involving cost may be set. The questions in algebra will, as a general rule, be such as are of direct use in solving geometrical, scientific, and technical problems.

First Year

Arithmetic and Mensuration

Revision of vulgar fractions, decimals, and percentages; conversion of one form into another; British and Metric units and their conversion; methods of measuring length, including length of a curve; degree of accuracy; averages; permissible approximations; square root; relation of circumference of a circle to diameter; time and distance; velocity; speeds of pulleys and belts; angular velocity; areas of plane figures—rectangle, triangle, parallelogram, circle, and other figures made up of these; relation between perimeter and area; volume and weights of prisms and cylinders; practical applications.

Algebra

Use of signs and brackets; powers and roots; products; factors of such expressions as—

$$ac + ad + bc + bd,\ x^2 + 2xy + y^2,\ x^2 - y^2;$$

geometrical illustrations; application of the difference of two squares to problems in arithmetic and mensuration; simple equations; manipulation of formulæ.

Second Year

Algebra

Simple equations and simultaneous equations of the first degree involving two unknowns; factors of expressions of the form: $px^2 + qx + r$, $x^3 \pm y^3$; us of factors in simplifying fractional expressions; simple problems involving indices and surds.

Logarithms

Use of logarithmic tables; evaluation of simple formulæ.

Graphic Methods

Statistical graphs; plotting changes of position and calculation of change of direction; determination of real distances on maps and plans.

Trigonometry and Mensuration

Similar figures; sine, cosine, and tangent; use of trigonometrical tables; application to practical problems; extension of mensuration to sphere, cone, and pyramid.

Ratio, Proportion and Variation

Treated arithmetically and algebraically, with geometrical illustrations.

The Equation of a Line

Plotting of observations and experimental results; errors of observation and experiment; interpolation; plotting of $y = ax + b$; significance of the constants, including the special case $ax + b = 0$.

Practical Drawing

(*a*) Drawing, in the Preparatory Senior Technical Course, serves three purposes—(*i*) the students acquire a knowledge of the more important geometrical facts and relations; (*ii*) they obtain some facility in the use of instruments and the commoner constructions of plane geometry; and (*iii*) they learn how to represent a solid object on a flat surface. The first aim is more important in the first year, the third aim in the second year, and the second aim should be kept in view in both years.

(*b*) In plane geometry the work should not be limited to the drawing of figures from instructions. The properties of circles and of parallel lines, and the conditions of congruence of triangles and other figures should be established by drawing, measurement, the use of tracing paper, and other experimental methods. Students should be able to state clearly the chief geometrical facts and relations, as well as to apply them to the solution of problems.

(*c*) Too much attention should not be paid to the representation of geometrical solids and objects in unusual positions, or to sections which rarely, if ever, occur in practice. The teacher should aim at training his students to make and to read simple working drawings such as they will meet with in the textbooks used in technical schools. They should learn to choose suitable scales; to build up views round centre-lines in all appropriate cases; to project views correctly from one another; and to clean up the drawings. Actual objects should be used wherever possible in preference to flat copies, and the drawings should be dimensioned.

First Year

1. Use of instruments; tests for accuracy of straight-edge and squares; the mechanical drawing of parallels and perpendiculars, and the measurement and construction of angles.

2. Circles—radius, diameter, and chord; bisection of lines and angles; construction to find the centre of a circle; angle in a semicircle; relation between angles at the centre and the circumference subtending the same arc.

3. Tangents—construction of a tangent to a circle at any point on the circumference or from any point outside.

4. Properties of parallel straight lines; construction.

5. Properties of triangles—any two sides greater than the third, the sum of the interior angles, the relation of the exterior to the two interior opposite angles; construction of triangles from given data; conditions of congruency.

6. Properties of rectangles; the diagonal divides the rectangle into two equal triangles; the theorem of Pythagoras; properties of parallelograms; dependence of areas of parallelograms and triangles on base and altitude; construction of regular hexagon.

7. Solid geometry—rectangular and triangular prisms and cylinders, development, plan, front and end elevations; application to the projection of simple objects.

8. Freehand sketching (including isometric and

oblique views), with approximate dimensions, of simple geometrical models and objects.

(NOTE. *In the examination credit will be given for a neat style of drawing, including lettering and dimensioning.*)

SECOND YEAR

1. Construction of triangles and polygons from given data; reduction of a polygon to a triangle of equal area.

2. Similar figures; division of a line; scales; construction of a fourth proportional to three given lines and of a third proportional to two given lines; construction for a mean proportional.

3. Simple loci; circle and ellipse; simple linkages.

4. Tangents; problems involving lines and circles in contact.

5. Use of isometric and oblique projection in the representation of simple machine and constructional details.

6. Orthographic projection; the planes of projection; simple problems relating to points, lines, and planes; representation of solids, including the cube, prism, cylinder, and pyramid, with developments of their surfaces; sections, change of ground line.

7. The sketching and subsequent drawing, in orthographic, isometric, and oblique projection of simple machine and constructional details.

NOTES

1. In the examination a drawing may be given of which finished drawings or sketches of only one detail may be required.

2. Attention should be paid to lettering and to the use of correct centre lines, and to the selection of dimensions for the setting out of the work, not merely for drawing, but also as needed in the actual making of the objects depicted.

3. A considerable degree of skill in the use of the pencil, without reliance on compasses and other instruments, should be aimed at.

The Needs of Girls

So far we have said little, directly, of the special needs of girls in Senior Schools. This is not because we deem their special requirements of less importance than those of boys, but rather because the amount of common ground in mathematics for boys and for girls in the Senior School is very great.

There are, however, certain points of difference which must not be overlooked, especially in the more advanced sections of the subject. These differences are concisely expressed in the *Handbook of Suggestions* as follows—

> Certain differences of conditions, interests, and ability necessitate differences in the selection and treatment of the subject-matter for more advanced courses in mathematics for girls and boys respectively. In the first place, less time is generally available for the subject in girls' schools, and the effect of this is accentuated by the somewhat narrower scope of the average girl's out-of-school experience. Moreover, as girls have no concurrent instruction in wood work or metal work, and as they frequently study biological in place of physical branches of science, they meet fewer concrete applications of geometry and miss many opportunities for practice in measurement. It should not be assumed, however, that those aspects of the physical world and of social life, which are better understood by persons who have had a mathematical training, are necessarily outside a girl's interest. Much of the girl's difficulty in grappling with a mathematical problem may be due to want of familiarity with its subject-matter and inability to visualize the conditions involved in the problem. More responsibility is, therefore, thrown on the teacher of girls for providing a basis of reality for their mathematical work. The fact that the mathematical course for girls in Central Schools and Advanced Classes is at present frequently academic rather than practical may be due to the more limited opportunities of many women teachers and to the difficulty which they themselves have of relating their mathematics to experience. A purely academic course, with its demands on powers of abstract reasoning, is, however, scarcely suitable for pupils of either sex at this stage.

A course suitable for girls should accordingly be as practical and realistic as possible.

Among the topics which, by common consent, ought to be included in any general course for a Girls' Senior School are the following—

1. Domestic Arithmetic. This will include domestic applications of every kind—buying and selling; bills and accounts; thrift and savings; household budgets; economical purchasing; buying for cash, and buying by instalments; rates and taxes; and, indeed, every possible topic which occurs in the everyday life of the average housewife.

2. Geometry and mensuration applicable to papering and carpeting rooms, to the planning and furnishing of a house, to needlework design and to other handicrafts for girls.

3. Commercial applications. These will be developed particularly in schools which have a commercial bias, and the possibilities of this particular aspect of the subject have already been indicated.

4. Certain aspects of the arithmetic of citizenship, e.g. insurance, local and national expenditure and income and other topics.

5. Such parts of the work in algebra and graphs, already outlined, as will be of value in dealing with the topics indicated above.

Having in mind these special needs of girls, we now venture to suggest, in detail, a syllabus of work for an ordinary non-selective Senior

Girls' School. This syllabus has been fully worked out by the writer and a headmistress of great experience in the well-known series of *Common-sense Arithmetic for Senior Girls*.

A Complete Syllabus for Girls

(as contained in detail in the books of *Common-sense Arithmetic for Senior Girls*—F. F. Potter and V. L. Hilliard—Sir Isaac Pitman & Sons.)

First Year (Book I: Pupils Aged 11–12 Years)

First Half-year	*Second Half-year*
Revision—Simple Rules.	Revision—Simple Rules.
,, Money Rules.	,, Money Rules.
,, Compound Rules.	,, Weights and Measures.
Buying and Selling.	Simple Costs.
Simple Costs.	Bills.
Bills.	General Money Accounts.
General Money Accounts.	Time Exercises.
Buying by Instalments.	Home Calculations.
Weights and Measures.	Simple Practice.
Time Exercises.	Compound Practice.
Aliquot Parts.	Short Methods.
Practice.	Fractions—Rules.
Short Methods.	,, Problems.
Fractions.	Decimals—Rules.
Decimals.	,, Problems.
Ratio.	Ratio.
Direct Proportion.	Direct Proportion.
Inverse Proportion.	Inverse Proportion.
Averages.	Averages.
Area—Domestic.	Area—Walls and Floors.
,, General.	,, Gardens and Paths.

In addition to the above topics, all of which are fully worked out, Book I contains a number of Revision Exercises placed at regular intervals throughout the book.

Second Year (Book II: Pupils Aged 12–13 Years)

First Half-year	*Second Half-year*
Revision—Simple Rules.	Revision—Simple Rules.
,, Money Rules.	,, Money Rules.
,, Weights and Measures.	,, Weights and Measures.
Buying at Sale Time.	Buying and Selling.
Simple Costs.	Short Methods.
Bills.	Miscellaneous Money Problems.
Short Methods.	Time Exercises.
Money Problems.	,, and Distance.
Buying by Instalments.	Ready Reckoners.
Time-table Problems.	Local Rates.
Aliquot Parts.	Fractions.
Practice.	,, of Remainders.
Fractions—Rules.	Decimals—Division.
,, Problems.	Metrics.
Decimals—Rules.	Direct Proportion.
,, Problems.	Inverse Proportion.
Ratio.	Proportionate Division.
Direct Proportion.	Averages.
Inverse Proportion.	Percentage.
Averages.	Simple Interest.
Percentage.	Practical Exercises.
Simple Interest.	Area.
Area.	Circumferences of Circles.
Volume.	Volume.
Algebraic Methods.	Algebra.
Graphs.	Graphs.

As in the case of Book I, Book II contains ample Revision Exercises, in addition to the above.

Third Year (for Pupils Aged 13–14 Years)

First Half-year	*Second Half-year*
Revision—Simple Rules.	Revision—Simple Rules.
,, Money Rules.	,, Money Rules.
,, Weights and Measures.	,, Weights and Measures.
Buying for the Household.	Buying for the Household.
Railway Travelling.	Short Methods.
Short Methods.	Gas and Electricity.
Gas and Electricity.	Money Problems.
Money Problems.	Time and Distance.
Time and Time Tables.	Ready Reckoners.
Practice.	Payments in the £.
H.C.F., L.C.M., Fractions.	Local Rates.
Problems in Fractions.	Fractions—Rules and Problems.
Decimals.	,, of Remainders.
Decimalization of Money.	Decimals—Rules and Problems.
Metrics.	Metrics.
Ratio.	Proportion, Direct and Inverse.
Direct Proportion.	Miscellaneous Proportion.
Inverse Proportion.	Proportionate Division.
Averages.	Averages.
Percentage.	Percentage.
Gain and Loss per Cent.	Simple Interest.
Simple Interest.	Mensuration and Drawing, including areas of simpler figures and circles.
Area.	Rectangular Volume.
Parallelograms, Triangles.	Algebra.
Circular Measurements.	Graphs.
Volume.	
Algebra.	
Graphs.	

An examination of this syllabus will reveal its main features.

In the first place it is concentric. The same topics are repeated each half-year, and in each year of the course. Thus, by repetition and extension, the pupils gradually increase their knowledge of any particular topic.

An examination of the books themselves will reveal the important part played in each year by *Revision*, for miscellaneous revision exercises are found throughout the books.

Again, a prominent feature is the attention given to those topics which appeal more particularly to girls, such as the arithmetic of the home, the shop, and the market. Yet, while due attention is given to these aspects, every effort has been made to preserve a logical, orderly, and mathematical sequence of work, while special attention has been given to Mensuration and Practical Exercises of many kinds, including Geometry, Graphs, and Algebra, work which we have noted to be in danger of neglect in some girls' schools.

A Complete Syllabus for Boys

Having outlined above a suitable course for the average Girls' Senior School, we shall now give a similar syllabus suitable for boys in a non-selective Senior Boys' School. This syllabus has been worked out in detail in the new series of *Common-sense Arithmetic for Senior Boys*—(F. F. Potter and T. Bamford—Sir Isaac Pitman & Sons).

FIRST YEAR (FOR PUPILS AGED 11–12 YEARS)

Revision—Simple Rules.
,, Money Rules.
,, Compound Rules.
Costs, Bills, and Accounts.
The Method of Practice.
Buying and Selling.
Short Methods.
Fractions—Rules and Problems
Decimals—Rules and Problems.
Exercises in Time.
Time and Distance—Speed.
Ratio.
Proportion—Direct and Inverse.
Practical Drawing—Introducing Ruler, Set-square, Protractor and Compasses.
Common Constructions and Scale Drawing.
Rectangular and Triangular Areas.
,, Volume.
Algebraic Methods.
Graphs.

SECOND YEAR (FOR PUPILS AGED 12–13 YEARS)

Revision—Simple Rules.
,, Money Rules.
,, Weights and Measures.
Buying and Selling.
Bills and Accounts.
Practice Methods.
Payments in the £.
Local Rates.
Ready Reckoners.
Short Methods.
Averages.
Fractions—Rules and Problems.
Decimals—Rules and Problems.
The Metric System.
Proportion—Simple and Inverse.
Percentage.

SECOND YEAR—(*contd.*)

Simple Interest.
Proportionate Parts.
Time and Distance—Speed.
Squares and Square Roots.
Practical Geometry and Drawing, involving the use of simple instruments and a knowledge of common constructions.
Mensuration—Area and Volume generally considered.
The Circumference and Area of a Circle.
Algebra—Formulæ and Equations.
Graphs.

THIRD YEAR (FOR PUPILS AGED 13–14 YEARS)

Revision—Number Rules.
,, Money Rules.
,, Weights and Measures.
Short Methods.
Payments in the £.
Ready Reckoners.
Practice.
Local Rates.
Averages.
Time and Distance, Speed.
Fractions—Rules and Problems.
Decimals—Rules and Problems.
The Metric System.
Proportion—Direct and Inverse.
Proportionate Division.
Percentage.
Simple Interest.
Easy Cases of Investments.
Squares and Square Roots.
Practical Geometry and Drawing.
Area—Rectangle and Triangles.
,, Parallelograms and Trapezoids.
Volume.
Circular Measurements.
Algebraic Exercises.
Graphs.

If the syllabus for boys, outlined above, is examined in detail, and compared with that given for girls, certain resemblances and certain differences will be at once apparent.

In general, especially in the first two years, it will be noted that the groundwork is fundamentally the same. Thus both boys and girls are required to consolidate their knowledge of the elements assimilated in the Junior School, and accordingly the "Rules" in Number, Money, and Weights and Measures are revised and extended. At the same time the fundamental processes in Vulgar Fractions, Decimal Fractions, and Metrics are steadily developed. Side by side with this, in both syllabuses, new methods and new topics, such as Practice, Ratio and Proportion, Averages, Percentages, and Interest are gradually introduced and expanded.

It is perhaps in the Practical and Geometrical Exercises that the books for boys differ most from those for girls, though the applications in each section of the books are "biased" according to the special requirements of the two sexes.

But all teachers are recommended to examine the books for themselves, and to form their own judgment as to their suitability for any particular class or school. In particular they would do well to examine the Transition Book (not given in detail above) which is intended for the use of *backward* pupils, boys or girls, in any year of the course.

Conclusion

We have now indicated in considerable detail the possible content of the subject of elementary mathematics in the average Senior School, and have sketched suitable syllabuses both for boys and for girls.

In conclusion, we propose to indicate briefly a few general points in the method of teaching the subject which will need the careful attention of teachers, if reasonable success is to be attained. Many of these points have already been alluded to incidentally in the preceding pages, and are collected here for emphasis and convenient reference.

The Teaching of a New Rule or Topic

The general method of approaching new work has already been indicated indirectly in numerous cases. It remains only to emphasize a few points which, by general agreement, should be borne in mind by the teacher of the average pupil in a Senior School. As in the case of Junior pupils, it is wise to make the approach to a new topic as inductive as possible. "Rules" should never be "given" if they can possibly be "discovered" by the pupils' own effort. This experimental and heuristic approach certainly occupies much more time, and the harassed teacher may sometimes be inclined to hasten the process by "telling" a result, but, if he can possess his soul with the necessary patience, he will find that the gain to the pupil is worth the extra time required. This is particularly true of formulæ in mensuration, and the wise teacher will explore these in all possible ways before requiring the formulæ to be memorized and applied.

Equally desirable in the approach to a new rule is the fact that the initial stages should be as real, concrete, and practical as possible. Ideally, new "rules" should arise out of new and urgent needs of the pupils, preferably out of some new problem or quest upon which the pupils are engaged.

Individual Methods—Mathematical "Sets" and Sections

Teachers to-day have grasped the fundamental fact that all members of a class of possibly forty pupils are not all at the same stage of development in mathematics (or indeed in any subject). The difficulty has been met in various ways. In some schools, following the method of large Secondary Schools, pupils are re-grouped, according to ability, specially for mathematics, and the plan is claimed to work well. Other teachers group within the class itself, while in the larger Senior Schools there will be, in a "three-stream" school, at least A, B, and C sections in each year of the course. Yet, even in these classes, some arrangement in sections within the class is usually necessary. In a few schools the method of actual individual treatment is followed. These various methods are reviewed impartially by the *Handbook of Suggestions*—

> Some teachers allow each child to work at his own rate of progress. While this plan encourages self-reliance and effort, and obviates "marking time" on the part of the better pupils, it may make the proper organization of oral and practical work less easy. Many teachers, therefore, prefer to divide the class into two or perhaps three sections for arithmetic, each containing children at approximately the same stage, and to meet differences of ability by giving the brighter children more exercises of a problematic kind. This enables them to devote more attention to the less proficient children in the group. In small country schools more than three sections in the class may often be necessary. Another plan sometimes adopted with success in larger schools is to reclassify the pupils for arithmetic.

It will be seen at once that the value of the grouping adopted in any school for arithmetic and elementary mathematics will depend in the last instance upon the *kind of work* given to the different groups and sets, and much importance thus attaches to the textbook or class-book selected for use. In attempting to provide books which may be used by all members of a class the writer and his co-operating colleagues have, in the series of *Common-sense Arithmetic Books for Boys*, adopted a double-page arrangement of each exercise. In this the first page is mainly straightforward calculations and "mechanical" sums suitable alike for all members, even of a "C" class, while the second page consists mainly of problems grouped in equal numbers as Easy and Harder. Thus an "A" section might work the whole of the exercise, while a "B" section might omit the "Harder" examples. Further, a *Transition* Book has been provided, which may be used with the very backward pupils in any particular year of the course.

The End of It All

Having discussed, through many pages and sections, the possibilities in the teaching of arithmetic and elementary mathematics in the new Senior Schools, we have to ask ourselves, at the end as at the beginning, what it is that we as teachers are really striving to attain, for unless our aim is clear, our work will be largely vague and formless.

The old double-aspect of the subject as both utilitarian and disciplinary has been largely discarded, the former view being too narrow and the latter too grim and deterrent. The immediate "usefulness" of much of the work is to-day not always apparent, while on the so-called disciplinary side even philosophers have ceased to look upon drudgery and aimless tasks as of necessity having any particular virtue.

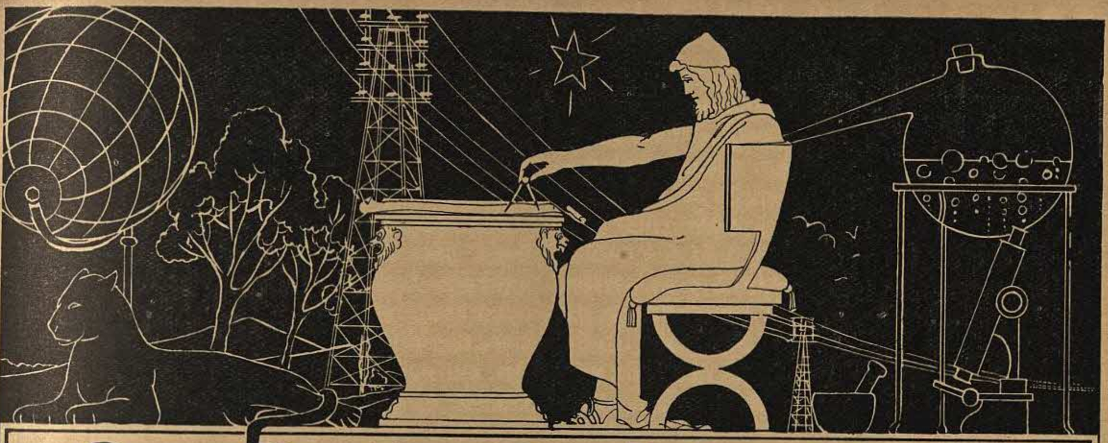
Accordingly we must review and restate our whole objective, which may be briefly expressed as follows—

1. It is our duty to hand on to successive generations of pupils the condensed and codified wisdom of the human race, and of this heritage the simple truths of arithmetic and mathematics are a not unimportant part.

2. It is our duty to cultivate and foster in all possible pupils the *mathematical habit of mind*, by which alone the material world can be reduced to reasonable order.

Beyond this, we should beware of claiming too much, for mathematics is non-ethical in this sense, that no amount of "domestic" arithmetic will prevent a woman from being extravagant in her home or in her dress, and no amount of higher mathematics will of itself minimize the amount of betting and gambling which is a feature of the modern world.

We are thus reduced to the simplest elements in stating our object. We teach arithmetic and elementary mathematics as being in the first place the rightful heritage of the pupil, and to some extent essential in dealing with the modern world, and in the second place because we believe that the habits of patience, concentration, and accuracy thus inculcated are not without value as elements of human character.



SCIENCE

ORGANIZATION OF SCIENCE SYLLABUS

The Science Course—Primary Difficulties

THE Senior School has only been in existence for a very few years, but already most teachers and other people connected with the new type of school have come to the conclusion that the subject of the curriculum which presents the greatest difficulty is the one with which this section of *The Practical Senior Teacher* deals, Science or, to use a more exact term, "Natural Science." We use the term Natural Science to distinguish that part of scientific study with which we shall deal from Mathematical Science, to which much of what is often included in the science course more properly belongs.

The difficulties referred to above arise chiefly in connection with the content of the Science Syllabus, and to a less degree with the method of presentation. What has been done previously in the Secondary Schools is no help; rather would one say that a scheme of science work which is modelled on the normal secondary school scheme will be a failure. We have to remember that the idea underlying secondary school schemes is that they are preparatory in type; rightly or wrongly there has always been the traditional idea that the function of a secondary school is to prepare for the university, and schemes have been drafted accordingly. Even where secondary schools have been bold enough to depart from this tradition, they have had to prepare schemes providing for a course which will last up to a pupil's 19th year.

The Science Syllabus—Governing Factors and Aims

The pupils in Senior Schools will have normally a three-year or a four-year course, and we have to face the fact that for the majority of the pupils there will be no further formal education. Our course, then, should not be preparatory; it must be complete in itself; it should resemble a complete short story, rather than an instalment of a lengthy serial. We must try to give our pupils a broad general grasp of scientific knowledge, such as an intelligent man living in the world to-day ought to have if he is to live a full and happy life. We shall have to remember that science is not so much a subject as a method of thought, and therefore we shall endeavour to teach our pupils to think clearly and logically.

Senior pupils at the end of the science course should have learned to observe and understand the things which lie around them in everyday life; their science should be connected with the phenomena which come, or are likely to come, within their personal experience: such things as the industries and natural products of an area should help to determine the content of the science course. The science syllabus should be adjusted to the interests of the pupils. Many schools, for instance, have particular subjects in which (often as a result of the enthusiasm of one member of the staff) a great interest is taken—in this one it will be gardening, in that one geography, in another perhaps handicrafts; the science course should take this into account and make use of interests already stimulated. The writer has seen in one school an excellent first-year science course based almost entirely on weather and seasonal change observations, a course that included something of most of the separate branches of science—physics, biology, geology, and even some chemistry. Naturally, too, the syllabus will be governed by the capacities of the pupils and by the facilities in the way of rooms, equipment, and apparatus which are available.

From what has been said above it will be seen that it is undesirable that there should be any kind of uniformity in science courses; even in the same area, if there is any kind of life in the science teaching, courses will vary between school and school.

Content of Science Syllabus

It is important that for our purpose we shall ignore the traditional logical divisions of natural science into chemistry, physics, geology, biology, and so on. Our syllabus must include something from all these branches of science. Naturally, if we consider what has been already written, we shall realize that more will have to be taken from some of these subdivisions than from others.

Chemistry, for instance, is not a subject which can receive anything like adequate treatment in the short time available in the Senior School: in the greater part of the elementary work it is not obviously connected with everyday life, and the commonest substances are the most complex chemically, so that beyond perhaps the chemistry of air and water little can profitably be attempted in this subject. It will be noticed that in the science section of *The Practical Science Teacher* no attempt has been made to devote a separate sub-section to chemistry; such chemistry as is contained in this work comes incidentally in connection with other sections.

Physics, or physical science, has a very prominent part in the world to-day; the electric light and electric irons in our homes, our wireless apparatus, our bicycles and motor-cars, the construction of several common domestic utensils, our methods of cooking, the very choice of clothes to wear—in all these things we have examples of the practical application of the principles of physical science. Obviously, therefore, our science teaching in the Senior Schools will include much which is usually classed under the heading of "Physics."

An educated man ought to have some knowledge of the natural world around him—of the earth and of the different forms of life which it supports; we must endeavour, then, in the time at our disposal to teach at any rate some part of those branches of natural science which treat of living organisms and of the structure of the earth itself—Biology and Geology. Many teachers, particularly in rural schools, have found that the latter subject appeals strongly to children, and it has the advantage that the materials are easily accessible.

A knowledge, even if it be an elementary one, of the structure and functions of living bodies, and of the laws of health built up on this knowledge, is bound to contribute something to the improvement of the human race; and, although this knowledge is likely to be one of the results of the teaching of biology, it has been deemed to be so important that there have been included in this book special sub-sections dealing with the structure and functions of the human body, and the laws of health derived from a knowledge of bodily structure and functions.

Arrangement of the P.S.T. Science Section

It will be seen that the Science Section of *The Practical Senior Teacher* is divided into eight chapters. Three of them deal with those three of the great logical divisions of natural science which can most readily be taught, in elementary schools—physical science, biology, and geology (we have seen already why no separate chapter on chemistry has been inserted), one chapter, "Domestic Science," covers a subject for which there will usually be a separate teacher, and the remaining four chapters, on Hygiene, Child Care, Dietetics, and First Aid, deal with the application of natural science to particular human problems.

The traditional headings to the chapters have been retained for two reasons, (*a*) for the sake of convenience, and (*b*) because it is important that each sub-section shall be the work of an acknowledged expert. One must repeat, however, that in teaching natural science in Senior Schools it is important that the formal boundaries between the different branches of science shall disappear, as indeed they have done to a certain extent in such subjects as hygiene—in what may be called perhaps the *Applied Natural Sciences.* Although the textbook may be arranged in formal divisions for such good reasons as those given above, it is the task of the teacher to draw up for himself the course which suits his own school best; from the same textbook an almost infinite variety of courses may be compiled.

We have already made the point that the science course must not be an isolated thing; it must take into account environment, time available, and interests already stimulated; this gives us a principle which will govern both our choice of subject-matter for our science syllabus and the method which we shall follow in teaching.

Method of Presentation

Instead of following the older tradition of giving a series of lessons in one of the formal branches of science, and giving examples to illustrate the principles as they arise, we shall rather take the common experiences of daily life and familiar apparatus designed to make man's work easier or to add to his comfort, and ask ourselves "Why?" and thus come to underlying principles. There must, of course, be some kind of system about the course, but one feels that it is better to have obvious discontinuity than that our science teaching should be divorced from the work-a-day world.

Every boy or girl who has been through our course must have a genuinely practical knowledge of science. A girl who has "learnt electricity" at school and cannot replace an electric fuse which has "blown," or has to take her electric iron to the electrician each time there is a fault or break in the wiring, is a witness to the worthlessness of the teaching which has been given to her.

Both the course itself and the teaching method should be built up on the solid principle of proceeding from manifestations of natural laws to the laws themselves; after all, that is how scientific investigation has largely proceeded. Man had observed certain phenomena in the world about him and he had even made use of them for his own ends before he discovered the principles or laws underlying them, and before he found out which phenomena were associated with one another.

Example of a Science Course

Let us take an example of how a course might be drawn up for a girls' Senior School—a course in "domestic science"—used in a different sense from its usual one, when the term "domestic science" is regarded as meaning "housecraft." We might begin with the elementary constituents of foods—protein, starch, sugar, fats, mineral salts, and water, and the functions of each of these constituents, showing, for instance, how starch, sugar, and fats form one group. The separation of curd (flesh-forming), cream (heat-giving), and whey (water) from milk as a typical food can be easily carried out, and similar experiments can be performed on other foods (e.g. bread, egg, and meat). Then we might touch on the inter-relation of starch and sugar, and the conversion of the former to the latter as part of the digestive process. The passing of certain fluids through membranes and the exclusion of others by the same membranes is easily illustrated experimentally, and we can introduce simple experiments in capillarity and surface tension, all of which are associated with digestion and blood circulation.

Then there might be an investigation into what happens to the air when we breathe. What happens when plants breathe? Notice the different results obtained with plants (*a*) in sunlight, (*b*) in the dark. Comment also on the usefulness of open spaces planted with trees and shrubs in large towns (see colour plate opposite, which shows one of London's many "lungs"). Compare the breathing of animals and plants with the burning of a fire. From this it is an easy transition to a series of lessons on combustion and flame—the mixture of air with coal gas, and its effect; the gas-ring flame, gas fires, incandescent gas-light, and so forth.

The water supply, heating, and ventilation of houses, and the construction of domestic apparatus in daily use bring us into touch with important principles in physical science, e.g. pressures of liquids and gases (particularly air), radiation, convection, and conduction of heat. From this we can discuss clothing and why we change colours and materials at different seasons of the year.

Electricity is so largely used in the home to-day and comes so much into the housewife's daily life that a course for Senior girls must include a study of this subject. The electric current and its heating and magnetic effects are most important; electric irons, fires, lamps, and the use of fuses lead up to the former effect, and the electric bell is perhaps the best-known example of the latter. The chemical effect of the electric current need not concern us unduly in such a course as the one we are now suggesting. Nearly all that is contained in the pages devoted to electricity in the physical science chapter of this book could, with advantage, be included in this scheme.

Attached to most Senior Girls' Schools in these days is a school garden used largely in connection with housecraft lessons, and a study of the life-history and structure of common plants grown there should certainly form part of the course; to give one example of work that can be done in this connection, we mentioned the conversion of starch into sugar in connection with digestion; we can if we like follow this topic still further and deal with the different kinds of sugar, and the formation of starch and its conversion into sugar by plants. The sweet taste of some vegetable products that have been touched by frost is a matter of common experience; an investigation of this phenomenon is an interesting piece of work.

The processes of cooking and preparation of food can lead up to interesting science lessons, e.g. the use of yeast in bread, of baking soda or "baking powder" in cakes, and why a "vinegar cake" is so light. Cooking processes depending on boiling points are worth noting. Why the time of deep fat frying is shorter than for boiling, why we must make certain that our fat is really boiling when we fry, why foods to be fried must be wiped dry before being put into the fat, what "steaming" really means, the coagulation of white of egg and of similar substances in meat and the use made of this in cooking—an investigation of these matters can form a very useful part of a science course for girls.

Readers will understand that what has been written above is not meant to provide a rigid course for the Senior Girls' School. It is intended to be merely an illustration, and suggestive rather than exhaustive at that, of how a course to suit a given group of pupils may be developed from material such as that supplied in this volume. The chapters on, for instance, Child Care and Dietetics will obviously be drawn on very largely in other directions than those which have been already suggested for this kind of course.

Demonstration, Individual, and Group Work

We have already said that the Science Course must be practical, and much that has been written above is by way of amplification of that statement; there are, however, one or two more points which it might be well to make in this connection. For instance, wherever possible we must deal with real objects, and diagrams must be used to supplement, not to replace, actual handling of the objects—if we wish to explain the working of a vacuum cleaner we ought to have a vacuum cleaner before the class, to be examined and dismantled. Experiments should always be performed and not described; this does not mean that the pupils themselves must perform all the experiments in the course; demonstrations by the teacher are in many instances to be preferred to individual

Lincoln's Inn, the Headquarters of the Law in London

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practical work by the pupils: first, because of the limited time available; secondly, because, with the younger pupils at any rate, there is lacking the manual dexterity necessary to perform many experiments; and thirdly, because for many experiments in our course there will only be apparatus for one experiment of a given kind to be performed at a time.

It is difficult to strike a balance between demonstration and individual practical work. One feels, however, that at the present time there is more danger of overdoing individual practical work than there is of having too much demonstration. There must be some individual practical work of course, but it ought to be well within a child's powers both of manipulation and of comprehension. For instance, in the suggestions which have just been made for a "Domestic Science" Course for Senior girls, there might very well be individual practical work on the splitting up of milk, and obtaining cream, curd, butter, whey, and mineral salts from it. One group could separate the butter by shaking, another by dissolving out the fat and evaporating, a third obtain the curd, a fourth might evaporate and find approximately how much water was lost, and so on. This would provide variety, and yet there would be a link between the work of the different individual groups, and also there would be a connection between this lesson and the demonstration which presumably would precede and follow it.

There are two things connected with demonstrations that ought to be stressed. The first is that a demonstration should always be clear, clear as to what is happening and clear as to the results which the demonstrator hopes to attain. We may illustrate this in connection with experiments dealing with the electrical circuit: too often one sees so many wires used that the apparatus begins to resemble a wire entanglement and it is impossible for a child to follow the path of the current. At a recent refresher course conducted by the Board of Education's Inspectors, the writer saw a piece of apparatus designed and demonstrated by Mr. P. F. Smith; it consisted of a board bored with vertical and horizontal rows of holes about 2 in. apart, and a series of brass or copper strips of different lengths which may be plugged into the holes, leaving gaps where desired; into these gaps can be plugged batteries, switches, fuses, coils, lights, or whatever is required for a particular experiment. The whole thing is perfectly clear and easy to manipulate, and there are no coiling wires to confuse. Another advantage is that by making use of plugs instead of wire connections we are following the normal household procedure.

The second point one would like to make in connection with demonstrations is that, wherever possible, articles in general use should be employed rather than the orthodox science apparatus—household basins, empty tobacco tins, medicine bottles, and even tin kettles can all be used instead of the less familiar and more expensive evaporating dishes, test tubes, flasks, retorts, and the like. For instance, in the early stages of experiments with electric currents, if we wish to show that a current is passing, it is better to use a small flash-lamp bulb than any instrument of the galvanometer type: the former is an everyday article, and to see it lit up carries conviction; the latter is not as a rule within a child's ordinary experience, and the fact that a needle is deflected is not so convincing. Later on, of course, we may use the voltmeter and ammeter.

Science and Handicraft

Finally one would urge that there ought to be a very close liaison between the science room and the handicraft room; home-made apparatus can be exceedingly useful, and the very act of making a piece of apparatus impresses it on a child's mind. Obviously there ought to be a relation between the time taken to make a piece of apparatus and its use: to spend six hours on making a piece of apparatus which is used for six minutes is clearly difficult to justify in a school which has only a three-year course. Just as obviously, there is no benefit to be got from making a piece of apparatus which will not adequately fulfil the purpose for which it was intended, nor from constructing a piece which is flimsy or fragile. It is not of course possible, or desirable, to use home-made apparatus exclusively; but, where apparatus made in the handicraft room can properly be used for an experiment, it ought to bear comparison with the bought article in every quality except perhaps finish.

This statement may need a little amplification and explanation: it is possible, for instance, to make apparatus which will show clearly that metals expand when heated, and these pieces of apparatus ought to be just as good for their purpose as bought equipment; but to attempt to use home-made instruments to measure the coefficient of expansion of a metal would be unprofitable, and even foolish. What ought to be borne in mind constantly is the limit of accuracy attainable with the apparatus available; a realization of this is as much a question of craftsmanship as of science.

While we are on this part of our subject it may be well to say that our science in Senior Schools should in general be qualitative, and that accurate quantitative determinations may well be omitted from our schemes. To return to the example already used, it will be desirable in most Senior School courses to show that metals expand when heated, but the determination of coefficients of expansion would be out of place, even with precise instruments.

We have become accustomed to the idea that the science master must be something of a craftsman, and to the desirability of providing a carpenter's bench with a set of tools as part of the equipment of a science room, but it is not generally appreciated that a good handicraft master can, and will, carry out many of the functions of an extra science master, and that part of the science scheme can actually be worked out in the handicraft room. We can think of the work carried out in a handicraft room in connection with the science course as being of two types: (1) the carrying out of commissions for the science room; (2) the teaching of principles by actual construction. Here, for instance, is a list of electrical apparatus made recently in the handicraft room of a Senior School with which the writer is familiar—

Electric base-board (described above), electric bell, bell indicator, solenoid, electric motor, telephone (a complete installation between the handicraft room and the school), transformer (for "stepping down" A.C. current).

The telephone installation—in connection with which only the carbon granules, the insulated wire, and the batteries were bought—represents a piece of science teaching through actual construction; while making and fitting up the telephones the boys learned how and why a telephone works. The transformer, on the other hand, was a commission; it is of course a most necessary piece of apparatus in a science room where it is desired to use current from the mains; the teaching of the principles of electrical induction on which it depends would be carried out in the ordinary science lesson.

What has been written above necessarily applies particularly to Senior Schools for boys. Generally speaking, where girls are concerned the matter will resolve itself into a question of whether or not it is possible to get science room commissions carried out in a boys' handicraft room—a comparatively easy matter where the school is a mixed one, but more difficult where it is necessary to enlist the services of a neighbouring boys' school. On the other hand, at least one women's training college has a woodwork course at the present time, and the Board of Education have recently carried out in various parts of the country short courses for school-mistresses dealing with handicraft and the making of apparatus. Each year, therefore, more and more women teachers are becoming expert in the use of simple tools, so that even in girls' schools the woodwork bench and a set of tools may conveniently find a place in the science room and a certain amount of learning by construction ought to become possible.

PHYSICAL SCIENCE

INTRODUCTION

Scope and Treatment of the Course

SO wide is the scope of physical science that in a work such as this it is only possible to deal in partial detail with a few of the many topics suitable for pupils in Senior Schools. The eight Sections which follow might well form the basis of a three-year course, but there are many other topics which may be considered of equal importance, and some of them are suggested in bare outline in the paragraph *Additional Topics for Study*.

The essential points in dealing with a science topic are—

1. That it shall have an obvious bearing on the familiar facts and interests of the pupils' daily lives.
2. That the work must be an *investigation* followed by questions which challenge the pupils' intelligence.
3. That it should result in a few simple *tentative* generalizations based on the pupils' experience *as far as it goes*, and not involve the unintelligent learning of physical "laws" after a pretence of establishing them by a few crude and inadequate experiments.

The sections here given may be taken as an indication of the treatment to be aimed at in dealing with other topics.

Laboratory Work

A large and increasing number of Senior Schools are now being provided with suitably equipped rooms in which pupils can undertake real, if simple, practical work in science, and the methods suggested are primarily intended for use with such facilities. They will, however, with slight modification be found equally useful where only demonstration by the teacher is possible. A fair amount of simple apparatus is presupposed, but also, what is more important, facilities for the improvising of apparatus by the pupils and teacher. Some instruction must be given in such elementary processes as cork boring, glass tube sealing and bending, and work with small pieces of wood, wire, tinplate, and nails, but a high degree of finish in these matters is rarely necessary or desirable.

In many of the illustrations shown here the necessary stands and fixings have been omitted for the sake of clearness.

Additional Topics for Study

What Happens when a Fire Burns ; Air and Breathing. Heat necessary to start a fire; "lighting" and "blowing out" a flame; a fire needs air; part of the air used up by a flame; the composition of the air. Oxygen and nitrogen, their properties and importance. The similarity between burning and slow oxidization; rusting. Characteristics of "used" air; carbon dioxide. Most fuels are carbonaceous. Carbon dioxide in exhaled breath; necessity for, and function of, oxygen in breathing of people and animals. Oxygen and carbon dioxide in plant life.

Flame and Fuels ; Coal Gas ; How a Motor Engine Works. The parts of a flame; nature and adjustment of Bunsen flame; gas ovens, fires and irons. Types of gas lighting burners. How coal gas is made, purified, distributed, and measured. The gas meter. The "lighting back" of a Bunsen flame; explosive mixtures of coal gas or petrol vapour and air; how the internal combustion engine works.

Mechanical Work. Why it is "hard"; gravity; friction and means of reducing it—ball bearings; lubrication. How work is made easier in some common appliances; locks, gear and signal levers, piano and typewriter actions (levers); wringer, hand drill, carpenter's brace, sewing machine, lathe drive, bicycle (crank, wheel and axle, pulley); various uses of gear wheels, including clockwork; screw jack, vice, the wood screw (screws).

Why an Iron Ship Floats. Establishment of the principle that a floating (or a sunken) body displaces its own weight of water; the idea of density. Archimedes' principle; the flotation of ships, submarines, floating docks. Diving and salvage methods. The similar principle applied to gases; airships and balloons.

Further Electricity. Electric lighting and heating appliances; how an electric motor works; how a telephone works. How an electric current is produced: (*a*) chemically—various types of cells; (*b*) mechanically; induction; the principle of the dynamo treated very simply. How electric currents are detected and measured.

Seeing and Hearing—Light and Sound. How light is produced; the sun; flames; electric filaments. Light travels in straight lines; shadows. Mirrors and reflection—various devices depending upon reflection; periscopes, reflecting signs, etc. The bending of light—how a lens is used; simple arrangements of lenses. The pinhole camera; the lens camera; the eye as a "camera." Persistence of vision—how the cinematograph works.

How sound is produced—difference between musical and non-musical sounds; pitch; the principles of common musical instruments. How a gramophone works.

More Intensive Treatment of Suggested Topics

Not only may additional topics as suggested be included in the three-years' course, but it is highly desirable that the outline of the topics here given should be "filled in" and amplified.

The teacher may add considerably to the number of simple experiments so as to give further confirmation to the principles he wishes to establish—i.e. he may go more slowly but more thoroughly over the ground.

Every teacher should endeavour to obtain as many good illustrations as possible of the various applications of the principles learned. Many picture papers have excellent material for this purpose.

Some teachers may wish to include a more quantitative treatment of the topics. Except to some extent in the sections dealing with electricity, where some knowledge of volts and amperes is of the first importance, this has been omitted from the suggestions given. It can, however, very easily be included as an extension of the work, but it is essential that the *simple treatment of the essential principles involved in everyday things*, as suggested here, should come first. Without a thorough grasp of the relationships involved, quantitative work is liable to become a mere mechanical working of meaningless exercises.

The following sections suggest a suitable treatment of some of the important topics for Senior pupils.

I. WATER IN THE HOME

Water is one of the things that all men must have. So important is it that whenever we can we arrange to have it "laid on" to our houses so that we can get it by merely turning a tap. Even in remote country districts many of the better houses are now fitted with pumps, cisterns, and taps.

Why does Water flow out of the Tap?

EXPERIMENT. Fit up apparatus shown in Fig. 1. Fill the funnel and tube with water and close the nozzle. Try the nozzle in each of the positions *A*, *B*, *C*, *D*, and *E*; each time open the "tap" to see if the water will flow. Try it also with the rubber tube raised above the level of the water (Fig. 2).

(*a*) Will the tap run when it is higher than the level of the water in the funnel? (Yes or No.)

(*b*) What happens to the water in the tube when tap is open in positions *A* and *B*?

(*c*) Will the tap run when it is lower than the level of the water in the funnel? (Yes or No.)

(*d*) Does the raising of the connecting tube alter the flow of water from the tap?

Many large towns get their water from distant lakes high in the hills. From these the water passes through a closed pipeline—up hill and down dale—until it reaches the town reservoir or water store, perhaps passing through sand filter-beds to purify it. The reservoir is always higher than the highest tap in the town (Fig. 3). Other towns, in flat lands, which get their water from wells or rivers, have to pump it up into a

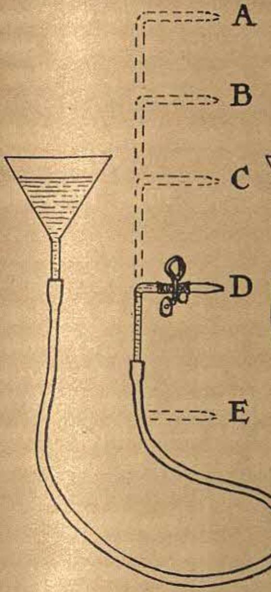


FIG. 1
Experimental "Tap" Positions for Nozzle

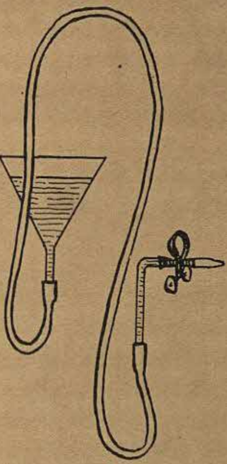


FIG. 2
"Tap" with Tube Raised

high water-tower, from which it descends to the taps in the houses.

Exercise. Find out where your home water-supply comes from, and make a diagram showing the path of the water from well or lake to your taps at home.

THE SCREW TAP

The pressure at the taps is often great, so that the tap has to be made as shown in Fig. 4. When the leather or rubber washer wears out it has to be replaced or the tap will leak.

Cisterns: The Ball Valve

For some purposes in the house a cistern is required, e.g. for flushing the lavatory drain. This has to have a tap made so that the cistern will refill as soon as it is emptied. The special tap, known as a "ball valve," used for this purpose is shown in Fig. 5.

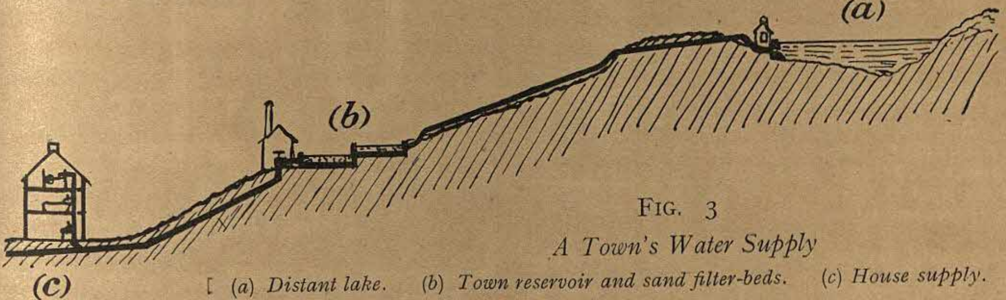


FIG. 3
A Town's Water Supply

(*a*) *Distant lake.* (*b*) *Town reservoir and sand filter-beds.* (*c*) *House supply.*

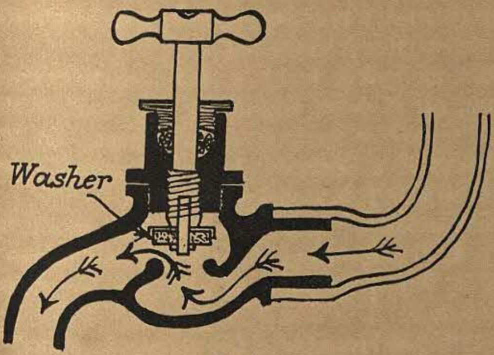


FIG. 4
Section of a Water Tap
When the tap is screwed down the washer closes the opening.

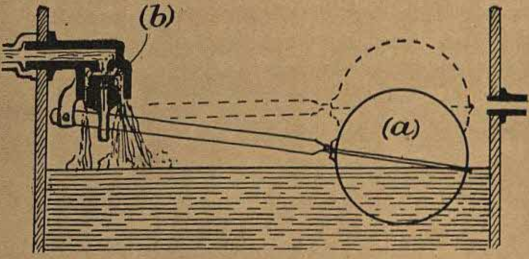


FIG. 5
A Ball Valve
(*a*) *Hollow copper ball float.* (*b*) *Rubber washer.*
When the float rises the washer closes the opening.

EXPERIMENT. You can make a "tap" which will turn itself off when the water rises, just as the ball valve does, though it does not work in quite the same way. Fix up the apparatus shown in Fig. 6, and arrange it so that when the water rises in the "cistern" (the funnel) the rubber supply tube kinks at *A*. Empty the "cistern" and the float falls, the supply tube opens and the water flows. You will need only a tiny dribble of water from the tap.

Filtering

Although water for town supply is chosen to be as pure as possible, it often needs filtering to remove solid particles and to make the water clear. This is generally done through beds of sand (see Fig. 3); in school you can get the same result by using blotting-paper or filter-paper.

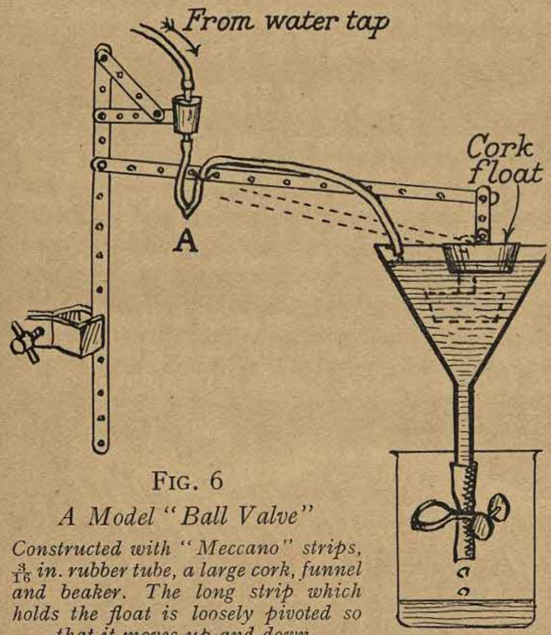
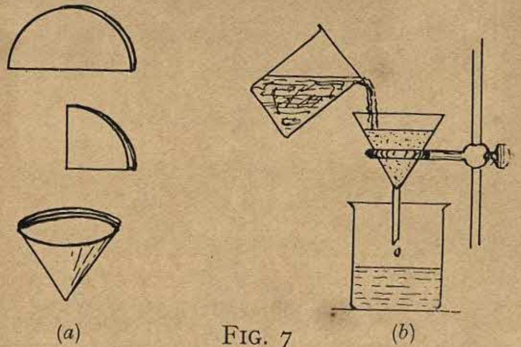


FIG. 6

A Model "Ball Valve"

Constructed with "Meccano" strips, $\frac{3}{16}$ in. rubber tube, a large cork, funnel and beaker. The long strip which holds the float is loosely pivoted so that it moves up and down.

EXPERIMENT. Fold a filter-paper as shown in Fig. *7a,* and put it in a funnel as Fig. *7b*. Pour some muddy water into the filter, taking care not to let it flow above the edge of the filter-paper.



(*a*) FIG. 7 (*b*)

Filtering

(*a*) Is the water which comes through muddy or clear?

(*b*) What becomes of the mud from the water?

Drainage

Just as water must come from a higher level to our homes, so it must pass on to a still lower level when we no longer need it. In seaside places the drains take the house waste direct to the sea; in other places the waste liquid is run to a low-lying part and allowed to soak away into the land; or, after being rendered harmless to health, generally through the action of bacteria (germs), it may be passed into a river which in turn carries it to the sea.

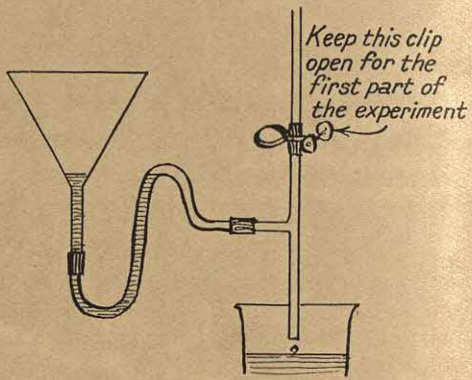


FIG. 8

A Model Drainage Trap

It would not do for drains in houses to be open pipes, for if so we should get the smell of the drains passing back into our homes. So the opening of a drain is always "trapped"—i.e. bent so that it is sealed with water.

EXPERIMENT. Fit up apparatus shown in Fig. 8. Fill the bend of the tube with coloured water. Now pour a quantity of clean water into the funnel.

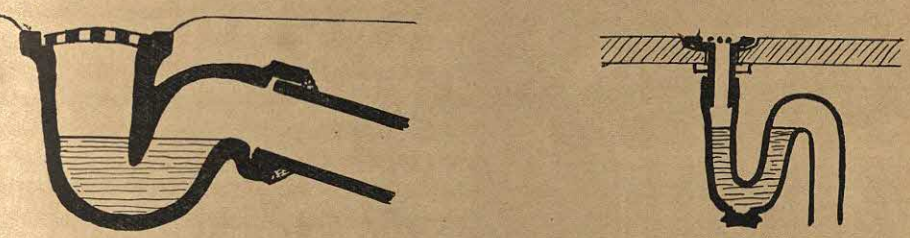
(*a*) What happens to the coloured water?

(*b*) What remains in the bend of the tube? Why is this part called the "trap"?

(*c*) Close the upright tube with a clip, and repeat the experiment.

What happens this time? Why is it necessary to have the open upright tube?

This apparatus is an almost exact model of a lavatory drain. The upright pipe, which is carried to the top of the house and capped with a wire cage, not only prevents the trap from emptying, but it also serves to ventilate the drain. The traps in a yard gully and under a wash-basin or sink are shown in Figs. 9*a* and 9*b*.



(*a*) *A yard gully trap*

(*b*) *A sink trap*

FIG. 9

Drainage "Traps"

Exercise. Trace out the traps in the drains in your home, and make sketches of them showing how they work.

II. AIR AND WARMTH IN THE HOME

Men cannot live without air and warmth. Our houses must have a good supply of fresh air: that is, they must be *ventilated*. They must also be *warmed*, and we shall find that warming and ventilation are closely connected — we cannot warm a room properly without ventilating it as well.

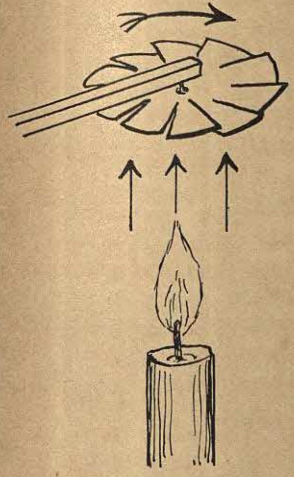


FIG. 10

Experiment to demonstrate Air Current from Flame

Air Currents

Out-of-doors the air is rarely still; although we cannot see it we know from many signs that it is moving—that a wind is blowing. Indoors also the air is on the move. We call indoor air currents "draughts," and, though we do not like them in the wrong places, we cannot do without the right sort of draughts if our homes are to be well ventilated and warmed.

EXPERIMENT. Make a paper windmill as shown in Fig. 10. If you blow on it, or hold it out-of-doors in a wind, it will rotate, and the way it rotates shows you the way the air current is moving. Hold the windmill over a candle flame.

(*a*) Is there a draught from the flame?

(*b*) In which direction is it moving?

EXPERIMENT. Fix two lamp chimneys into a cardboard box as shown in Fig. 11, with a lighted candle at the foot of one of them. Hold a smouldering piece of brown paper over the end of the other tube. Draw a diagram showing the way the currents flow in the tubes.

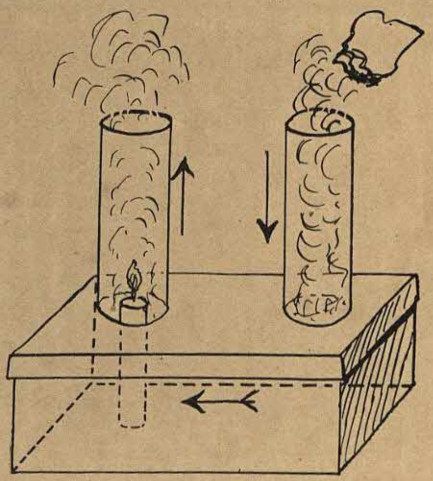
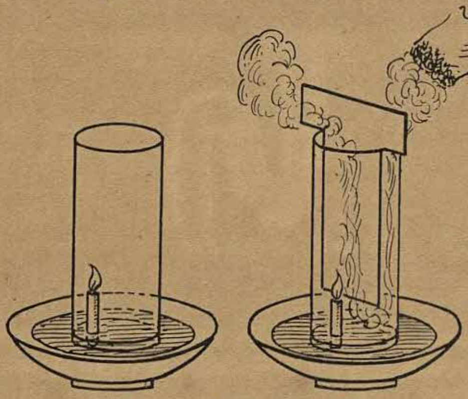


FIG. 11

Experiment demonstrating Path of Air Current set up by Burning

EXPERIMENT. Stand a large lamp chimney in a saucer of water, with a small candle at the bottom (Fig. 12*a*).



(*a*) FIG. 12 (*b*)

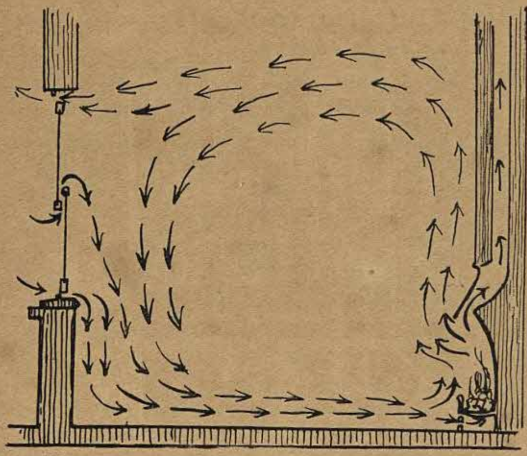
Experiment demonstrating Effect of Air Currents

(*a*) Does the candle burn well?

(*b*) Now put a piece of cardboard, reaching *nearly* to the water, into the chimney (Fig. 12*b*) and hold a smoking paper over the cool side. Does the candle burn any better?

(*c*) Which way does the cool air travel?

(*d*) Which way does the hot air travel?



(*b*) FIG. 13 (*a*)

Ventilation Currents in a Room with a Fire

(*a*) *Fireplace.* (*b*) *Window.*

Exercise. Explain why smoke from a chimney always rises to a good height, and hangs about in clouds; and why the smuts finally settle down to earth again.

Air Currents in a Warmed Room

Fig. 13 shows how the cold air, entering a room by the window, passes to the fire, where it is heated. As a result it expands, becomes less dense than cold air, and so tends to rise. Much of it passes up the chimney; some passes out into the room, where it circulates; some of this escapes by the top of the window; the rest cools and so becomes denser, sinks down, and again passes to the fire. Thus the effect of a fire is to keep a continual current of air in the room.

Measuring the "Hotness" of a Room: The Thermometer

A Fahrenheit Thermometer (Fig. 14) is used in this country for measuring the "temperature"—i.e. the "Hotness"—of the air. This instrument does not tell us how much heat there is in the room, for that would depend upon the size of the room, but it tells us how hot the room is. A room is comfortably warm when the temperature is 65° F.; on the hottest days in this country the temperature may go up to 90° F. in the shade; in the coldest weather as low as 20° F.

Exercises. (*a*) Read the thermometer and note the temperature in the room.

(*b*) Read the thermometer and note the temperature out-of-doors.

(*c*) Why is the thermometer best kept in the middle of the room, and not high up near the ceiling, near the window, or near the fire?

Ways in which Heat Travels

1. CONVECTION

When heated particles of air (or liquid, as we shall see later) form currents or draughts, so carrying the heat of fire, pipes, or radiator to a distance, the process is called *Convection.*

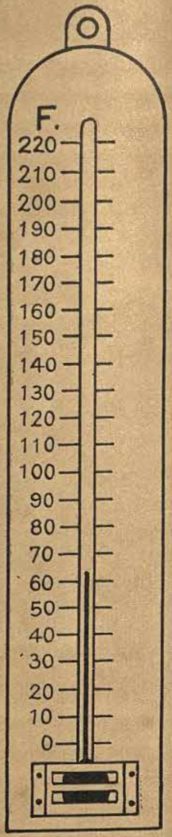


FIG. 14

A Fahrenheit Thermometer

Ventilation and house warming usually depend upon convection currents.

2. Radiation

How does heat reach us from the sun? Clearly not by means of air currents, as there is a vast distance of empty space between earth and sun. You know that you can feel the heat from a fire although you can feel no air currents, and you can feel the heat from an electric bulb although it is empty of air. *The heat travels directly through space.* This process is called *Radiation.* Some substances radiate heat better than others.

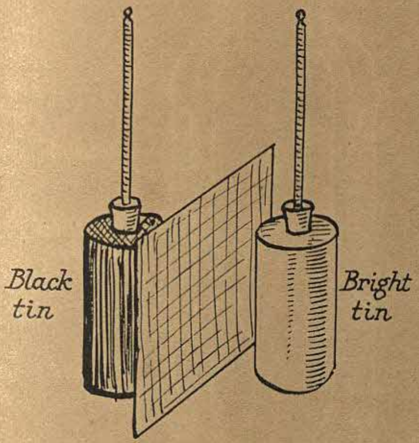


Fig. 15

Radiation Experiment

Experiment. The two tins (Fig. 15) are the same size and weight, but one is bright; the other is painted a dull black. Fill each with hot water; insert thermometers quickly; put the tins in a place free from draughts with a cardboard screen between them, and note the temperatures every minute.

	0	1	2	3	4	5	6	7	8 min.
Bright Tin temperature:	.	.	.	.	.	.	.	.	. degrees
Black Tin temperature:	.	.	.	.	.	.	.	.	. degrees

Which tin cools the sooner? Is a bright or a black surface better for radiating heat?

Experiment. Fill the same tins with cold water, and put them about 2 ft. from a hot fire, or in the bright sunshine. Take the temperature of each tin every three minutes. Which warms up the more quickly?

From these experiments we see that a dark surface radiates and absorbs heat better than a bright or polished one, and it is generally true to say that *substances which radiate heat best also absorb it best.*

Exercises. (*a*) Which will boil up more quickly: a polished kettle or a black one?

(*b*) Which will cool more quickly?

(*c*) Why is the ironwork of a stove generally black? Are radiators best painted in dark or light colours? Explain your answer.

(*d*) Why do we wear dark clothes in winter and light ones in summer?

3. Conduction

There is another way in which heat travels. After the fire has been lit for a time, every part of the stove becomes hot. If you put the head of the poker in the fire, the handle soon becomes hot. It does not seem to be by convection, for there can (surely) be no currents in the solid poker. It cannot be only by radiation, because your hand, placed at an equal distance from the fire, only becomes pleasantly warm. *The heat has travelled through the metal of the poker itself.* This process is called *Conduction.*

Experiment. Set up five rods of different materials—iron, copper, brass or aluminium, glass, and wood, as shown in Fig. 16. (The wood rod has the one end protected from the flame by a piece of metal wrapped round it. This small piece of metal will readily convey the heat to the wood.) Each rod must be dipped in paraffin wax (candle wax) for about half of its length. Gently heat the unwaxed ends of the rods together in a gas flame, and watch the wax until it is nearly all melted on one of the rods, then take the flame away and measure in inches the length of wax that has melted on each rod.

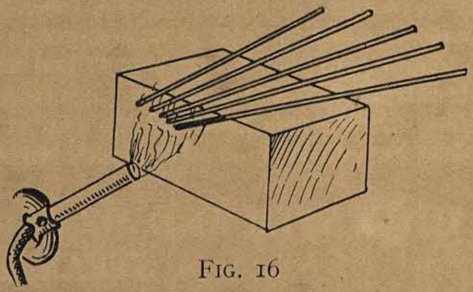


Fig. 16

Conduction Experiment

Length of Wax Melted

Copper . . . . in. Brass . . . . in. Iron . . . . in. Glass . . . . in. Wood . . . . in.

(*a*) Do all the rods conduct heat equally well?

(*b*) What kind of solid is a good conductor of heat?

It is easy to arrange experiments to show that air, water, brick, and clothing fabrics are bad conductors of heat.

Exercises. (*a*) Why is an iron building less comfortable than a brick one? What will it be like in the hot summer? In the cold winter?

(*b*) There is always a layer of air between our bodies and our clothing. In what way does this help to keep us warm?

(*c*) Which is more convenient to use—a metal teapot with a metal handle, or one with a wooden handle? Explain your answer.

The Thermos Flask

The working of this can be explained by what has been learnt. If a cold liquid is put in the flask it will remain cold for a long time; if a hot liquid is put in it will remain hot. A drawing of the flask as it would be if cut through (a "section") is shown in Fig. 17. Between the thin glass double walls of the flask is a vacuum, i.e. nearly all the air was pumped out before the glass was sealed. Thus there can be no *convection currents* to carry the heat in or out, except at the mouth, and this is kept closed; and very little *conduction* of heat can go on, since there is nothing but the thin glass and the stopper to conduct the heat in or out. The glass is brightly silvered inside, thus there is little *radiation* from its mirror-like surface, and it will absorb heat very badly. Thus the Thermos Flask is a very efficient article for preventing heat from passing into it or out of it.

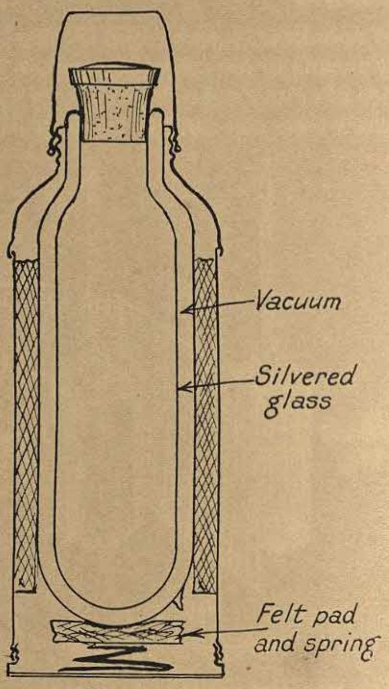


Fig. 17

Section of a Thermos (or Vacuum) Flask

Exercise. Examine a Thermos Flask which has been pulled apart, and draw a section of it, making notes to explain the various parts.

III. WATER AND HEAT—HOT-WATER SYSTEMS—HOW A STEAM ENGINE WORKS

Heated water is a very important thing in our lives. With it much of our cooking is done; we need it for washing; and steam, which comes from boiling water, is used to drive locomotives, ships, and machinery of all kinds.

What happens when Water is Heated Gently?

Experiment. Fit up the apparatus as shown in Fig. 18, and fill the flask and part of the tube with coloured water. Mark the height of the water in the tube when the water is cold. Gently warm the water, then allow it to cool again, noting the position of the water in the tube.

(*a*) What happens to the level of the water in the tube during heating, and during cooling? Can you account for this?

(*b*) If you observe carefully you will see that the level of the water *falls* a little before it begins to rise when the flask is heated. Can you account for this?

Experiment. Into a beaker of cold water

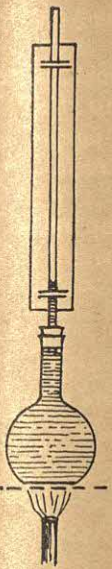


FIG. 18
Expansion of Water caused by Heat

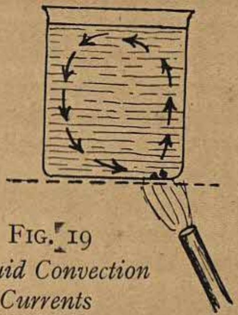
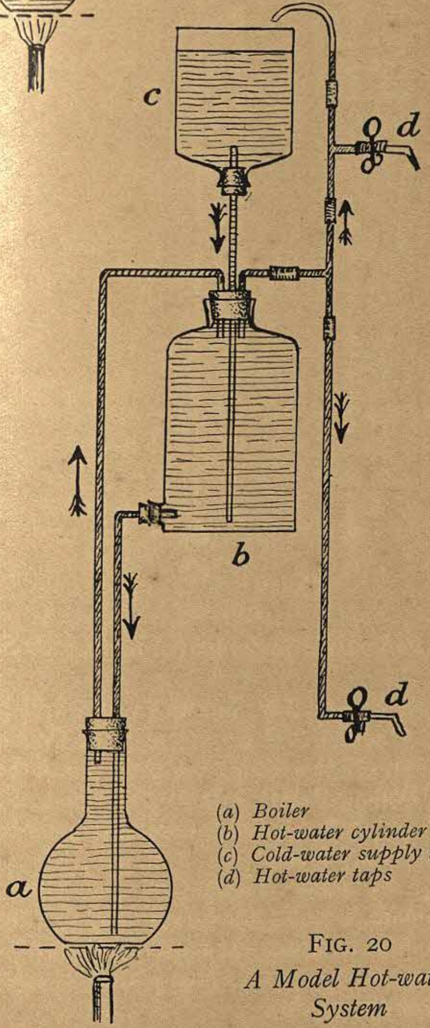


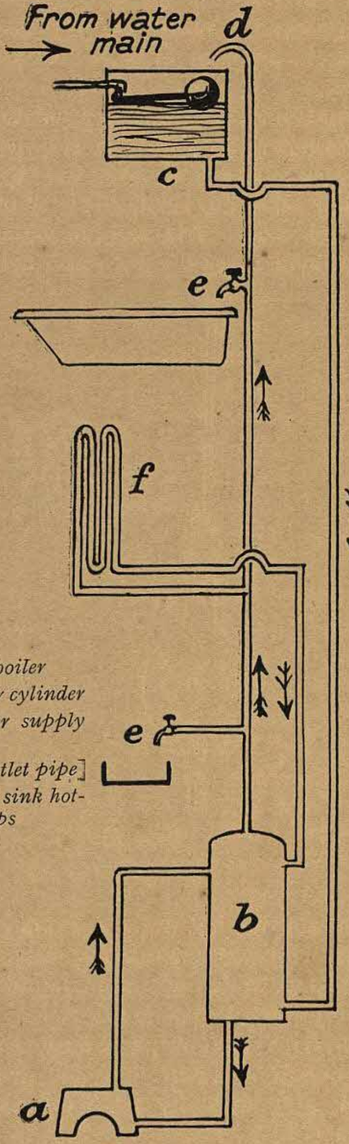
FIG. 19
Liquid Convection Currents



(*a*) *Boiler*
(*b*) *Hot-water cylinder*
(*c*) *Cold-water supply tank*
(*d*) *Hot-water taps*

FIG. 20
A Model Hot-water System

carefully place two or three crystals of potassium permanganate (or ink powder). Warm the beaker at one side (Fig. 19) and note the path of the coloured stream of liquid which starts from the crystals.



(*a*) *Kitchen boiler*
(*b*) *Hot-water cylinder*
(*c*) *Cold-water supply tank*
(*d*) *Safety outlet pipe*
(*e*) *Bath and sink hot-water taps*
(*f*) *Radiator*

FIG. 21
A Household Hot-water System

(*a*) Can you see any resemblance between the behaviour of heated water and that of heated air?

(*b*) Draw a diagram showing the direction of the currents in the water.

The currents in a hot liquid are called *Convection Currents*—the same name that is given to the currents in heated air. We use convection currents in order to circulate hot water in our houses.

EXPERIMENT. A group of scholars can fit up a model hot-water system as shown in Fig. 20. Hot water can be drawn from the taps shown, or from any other tap below the level of the water in the cold tank. Why can hot water be drawn from a point *above* the hot-water cylinder?

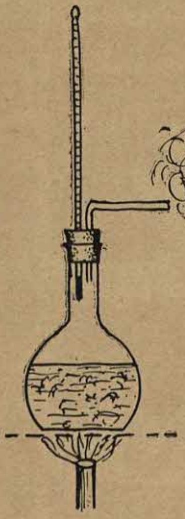


FIG. 22

Boiling Water

A household hot-water system is shown in Fig. 21. Hot-water circulating systems for radiator heating, which are often found in schools, work on much the same principle.

Exercise. Trace out, and draw a diagram of, the hot-water system in your own home or school, and show by arrows how the water circulates in it.

What happens to Water when it is Heated Strongly?

EXPERIMENT. Heat some water in a flask fitted with outlet tube and thermometer as shown in Fig. 22.

(*a*) At what temperature do bubbles first come off from the water? What do you think these bubbles are?

(*b*) To what maximum (highest) point does the temperature rise? What happens to the water when the temperature reaches this point?

(*c*) How long does the temperature remain at this point?

From this we see that the temperature of boiling water (and of steam) is constant—however much we heat the water the temperature will not rise further, but the water will go on steadily boiling. If we are using a Fahrenheit thermometer the boiling temperature (known as the "Boiling-Point"—or "B.P.") is 212°. If, however, we use a Centigrade thermometer the Boiling-Point is 100°.

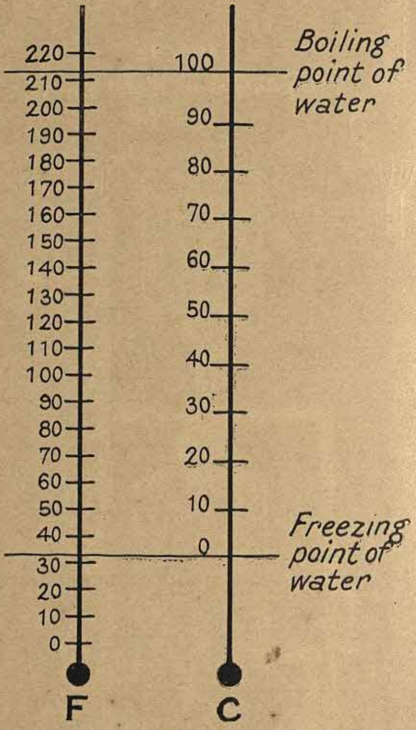


FIG. 23

(F) *Fahrenheit Scale and* (C) *Centigrade Scale*

Fig. 23 shows Fahrenheit and Centigrade thermometer scales side by side. The Centigrade thermometer is used in most continental countries for every-day purposes, and by scientists all over the world.

Can the Boiling-Point of Water be Raised?

EXPERIMENT. Fit up apparatus as Fig. 24. The opening at the top of the outlet tube is closed by the pointed end of the bent glass rod, which is held down by the small lead weight. Thus the steam cannot escape until the pressure increases sufficiently for this "valve" to be forced open. Boil the water and note the temperature obtained. You must be careful not to put too great a weight on the valve.

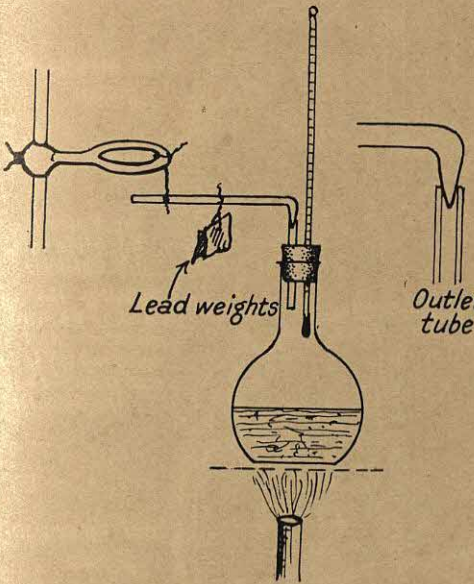


FIG. 24
Boiling Water under Pressure

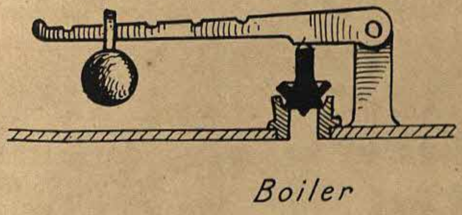


FIG. 25
A Lever Safety Valve

The Steam Engine Boiler and Safety Valve. A similar device is used in the boilers of steam engines, in which the steam is raised at a high pressure so that it can do more work than if it were kept at the pressure of the outside air. Fig. 25 shows a section of a weighted safety valve such as is used on stationary engines. On locomotives a spring is used instead of a weight to keep the valve closed.

Making Steam do Work—The Steam Engine

EXPERIMENT. Fit up the apparatus shown in Fig. 26. With the safety cock open, heat the water till it boils; then turn down the gas very low so that the water is only boiling gently. Now close the safety cock, and watch the effect on the glass "piston." Open the cock before the piston is driven right out of the "cylinder." What happens to the piston now?

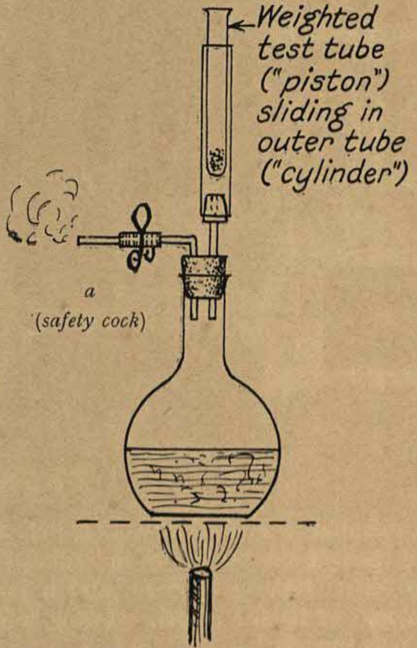
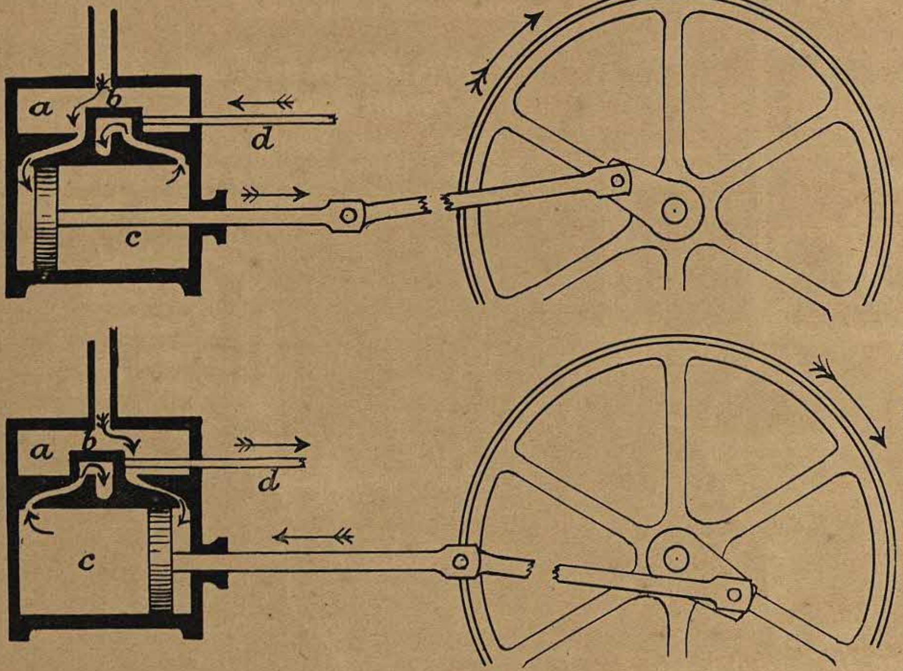

Weighted test tube ("piston") sliding in outer tube ("cylinder")
a
(safety cock)

FIG. 26
A Model "Cylinder and Piston"

This action is similar to, though less complicated than, that of a steam engine. A section of a steam engine is shown in Fig. 27. The steam enters the valve chest, and by means of the slide valve it is admitted to one side of the piston, thus forcing the piston out and starting to turn the wheel. But by now the slide valve has moved, so that it admits the steam to the *other* side of the piston, forcing it back again and continuing the turning of the wheel. The first lot of steam has now done its work, and is driven out of the cylinder by way of the exhaust pipe.



1st movement of piston

2nd movement of piston

(a) Valve chest
(b) Slide valve
(c) Cylinder

Actually the valve chest is BEHIND *the cylinder and the valve rod (d) is operated from the axle of the flywheel*

FIG. 27
The Slide-valve Steam Engine

Exercises. Make a diagram, and if possible a moving cardboard model, showing how the slide valve works.

If you can obtain a model steam engine, set it to work and make sure that you understand the action of all its parts. What kind of safety valve is used on toy steam engines? Make a sectional diagram showing how the valve works. Some model steam engines have cylinders which *oscillate*, i.e. move to and fro. Such cylinders, used only on toys, have no slide valve. Can you trace out how the steam is admitted to the cylinder, and how it is exhausted, in such a toy?

The Steam Turbine

EXPERIMENT. Fix up the apparatus shown in Fig. 28. The tin is an airtight one of the "lever lid" type. The "rotor" of the turbine is a 2-in. flat cork bung, into which tin vanes are fixed. The axle is a large darning-needle, which runs at top and bottom in dents (*not* holes) made by punching the lid of the tin, and the tin strip, with a blunt nail. Adjust the "rotor" so that it is well balanced and spins freely. In the lid of the tin, beneath the vanes, punch two small

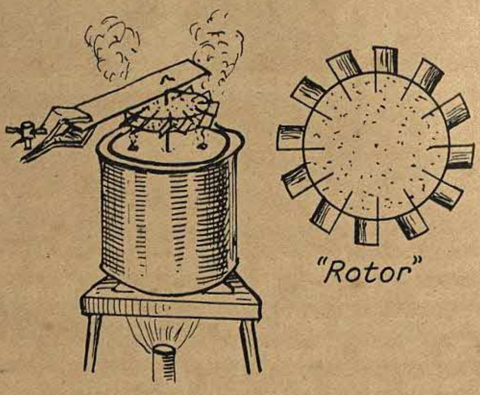


FIG. 28
A Model Steam Turbine

holes for the steam to pass through. Boil a little water in the tin, when the turbine should rotate very quickly.

This works on the principle of the turbine engine, used largely nowadays for driving electric dynamos, and for propelling steamships. In these large and powerful turbines there are many rotors, with hundreds of blades, and these are enclosed in a case (the stator) which has fixed vanes to direct the steam on to the rotor blades. Steam turbines run smoothly at a very high speed.

IV. MORE ABOUT WATER AND ITS CHANGES

Can Clear Water Contain any Solid?

EXPERIMENT. Allow drops of rain water, tap water, and sea water (or brine) to "dry up" on three clean watch-glasses (Fig. 29). Examine the dry watch-glasses carefully.

Which specimen of water leaves the most residue? Which the least?

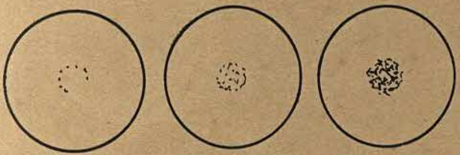


FIG. 29

Residue from Clear Water

(*a*) *Rain water. Practically no residue.*
(*b*) *Tap water. There may be a little residue.*
(*c*) *Sea water or brine. Much residue.*

Exercise. Does clear tap water contain any solid matter?

Examine the inside of a kettle that has been used for some time. Do you notice anything that will help you answer this question?

A substance that is held in water (or in any other liquid) so that it cannot be seen is said to be *dissolved*, and the resulting liquid is called a *solution*.

EXPERIMENT. Put into separate test tubes small quantities of sugar, salt, washing soda, sand, copper sulphate, potassium permanganate (or ink powder), coal, brick, and butter or suet respectively; add water to the test tubes and shake each up well.

(*a*) Which substances disappear in the water?

(*b*) Can you see any trace of the presence of any of the substances which have dissolved. If so, which ones?

(*c*) Can any of the first three substances be traced by their *taste*?

EXPERIMENT. To a test tube about one-third full of cold water go on adding powdered soda in small quantities, shaking up each time, to find out whether a time will come when no more soda will dissolve. Now heat the water, shake up, and add still more soda until you again have a small excess of solid in the tube.

(*a*) Is there a limit to the amount of soda which cold water will dissolve?

(*b*) Does heating the water help to dissolve more soda?

Solutions

Solutions are very important to us. Not only do we use them in preparing our food (salt in cooking; sugar in tea, etc.), but it is true to say that no food can do us good unless it (or some part of it) is dissolved by the liquids within our bodies. If a doctor wishes to alter or correct our bodily processes he gives us medicine in the form of a solution. Many substances which will not dissolve easily in water are readily soluble in other liquids.

EXPERIMENT. Shake up a tiny piece of fat in a test tube with methylated spirit. Repeat with hot soda solution.

(*a*) Why is methylated spirit of more use than cold water for removing grease stains?

(*b*) Why is soda often added to the water for washing dishes?

Hard and Soft Waters

EXPERIMENT. Make a soap solution by adding a few shreds of soap to some hot water and shaking vigorously. Carefully pour off the clear soap solution. Now take equal quantities (about 2 in. in a test tube) of rain water, tap water, and sea water (or brine). To each add some soap solution drop by drop, shaking between each drop, and counting the number of drops necessary to produce a "permanent lather," i.e. a foam that will last at least two or three minutes.

Rain Water: No. of drops of soap solution ....
Tap Water: ,, ,, ,, ,, ,,
Brine: ,, ,, ,, ,, ,,

Waters which do not lather well with soap are called *Hard Waters*; those which give a good lather easily are called *Soft Waters.*

Exercises. (*a*) In the last experiment, which kind of water is the hardest? Which is the softest?

(*b*) Look at the result of the first experiment you did in this Section (that with the three watch glasses). Can you suggest any connection between the amount of dissolved matter in a water and its hardness?

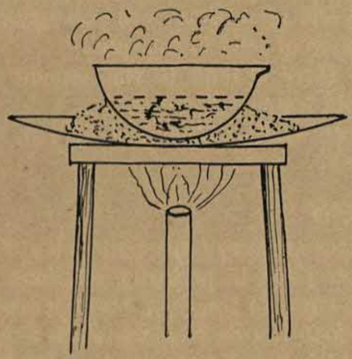


FIG. 30
Evaporating a Solution

Softening Water

EXPERIMENT. Using exactly the same amounts of water as in the last experiment, test the hardness of boiled water which has been cooled, and of tap water in which a small crystal of soda has been dissolved.

(*a*) What is the effect of boiling upon the hardness of tap water?

(*b*) What is the effect of adding soda upon the hardness of tap water?

(*c*) Explain how we make use of these facts in everyday life.

Removing the Solid from a Solution

EXPERIMENT. Make a strong solution of salt in water. Boil this solution in a porcelain bowl over a sand bath (Fig. 30) until all the water is driven off. What is the colour of the residue? What is the taste?

Recovering Pure Water from a Solution: Distillation

A solution may have taste or colour, but it is clear and so will pass through a filter. We can get the dissolved solid (the solute) from it by driving off the water (evaporating to dryness) as in the last experiment. How can we recover the water?

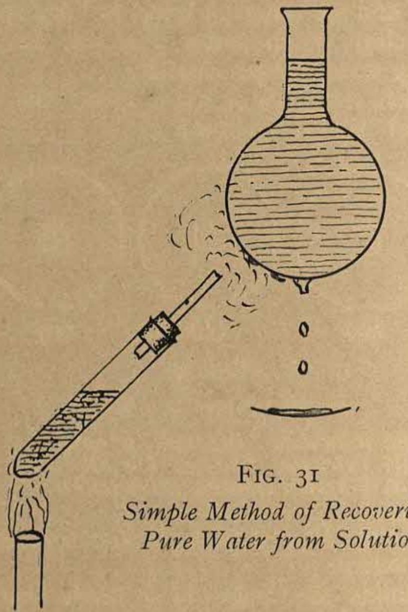


FIG. 31
Simple Method of Recovering Pure Water from Solution

EXPERIMENT. Fit up apparatus as Fig. 31. The large flask is full of cold water, but to start with is quite dry on the outside. Boil some brine in the test tube, allowing the steam to pass on to the flask. Taste the clear liquid which collects in the watch-glass. Does it taste of salt?

Repeat, using a coloured solution (potassium permanganate, or water coloured with ink) in the test tube. Is the liquid which collects in the watch-glass coloured?

This experiment enables us to recover only a few drops of the water, as much of the steam is lost; also the flask will soon get hot and fail to *condense* the steam. If we wish to recover all or most of the water we must use a "still"—the process is called "*distillation.*"

EXPERIMENT. Fit up the distillation apparatus as shown in Fig. 32. In the flask put brine that is muddy and coloured with ink. Observe the taste, colour, and clearness of the liquid (the "distillate") that collects in the receiver.

Distilled water is the purest of all water. It is used largely by scientists, by druggists for preparing medicines, and in electrical accumulators. The water used in ship's boilers continually passes through *condensers* and so is distilled; thus it carries no dissolved solid with it which would clog the boilers and pipes.

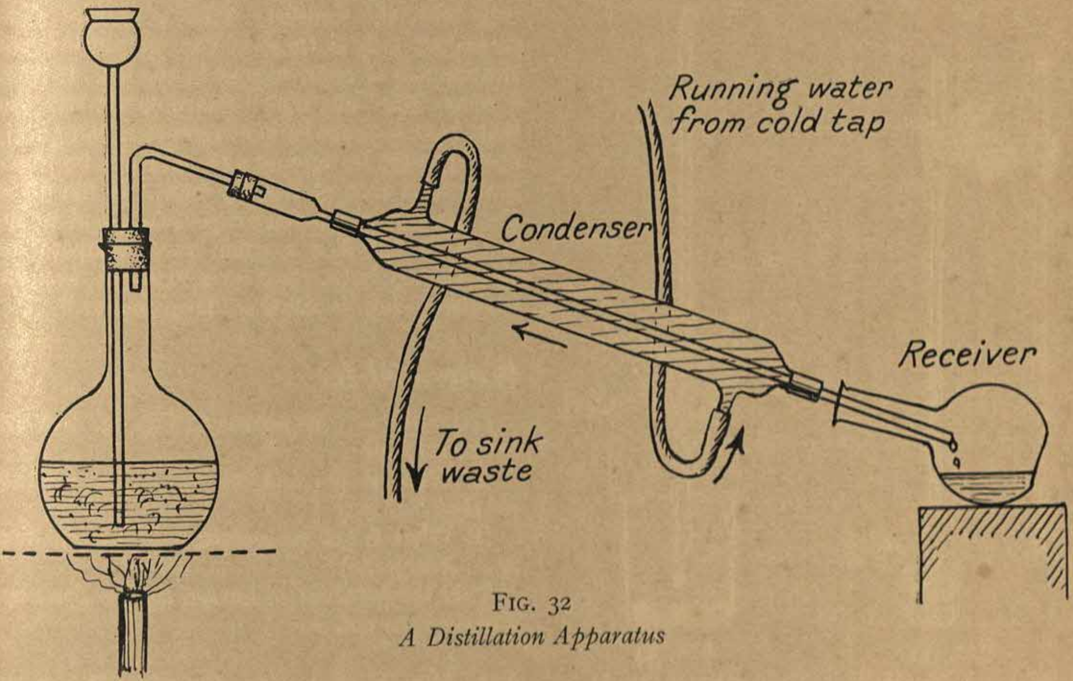


FIG. 32
A Distillation Apparatus

Water Vapour in the Air: Evaporation

As we have already seen, great heat is not essential to turn water into vapour, for clearly the drops of water which "dried up" on the watch-glasses in an earlier experiment must have turned into vapour although the liquid was not heated to boiling-point. We know, too, that wet clothes will dry in the air, and that wet roads, paths, and puddles "dry up" after rain. What happens to the water vapour which comes from these wet things when they dry?

EXPERIMENT. Put a small piece of wet rag in each of two watch-glasses. Put one watch-glass on a windowsill in a draught; cover the other with a glass beaker. Observe each after a few hours.

(*a*) Which rag has dried the more?

(*b*) What has become of the water which has come from each rag?

Exercise. Sometimes clothes have to be dried indoors. Where does the water vapour from these often condense?

Wind is more important even than warmth for evaporation—every housewife knows that clothes will dry on a windy day even if it is cold, for the air currents carry away vapour from the clothes as it is produced. The air is always more or less charged with water vapour, which we cannot see, unless it is condensed by something cold. The cold windows of a room or railway carriage become "steamed up," as we say, by the water which condenses on them; and a glass of cold water brought into a warm room immediately clouds over with moisture. In cold weather we can observe the condensation of the water vapour of which our breath is always full, for our breath seems to "steam." If we breathe on a cold mirror the water vapour condenses upon it.

Evaporation Takes Up Heat

Although the temperature of Boiling-Point is not necessary for slow evaporation, yet whenever water turns into vapour, whether slowly as in drying, or quickly as in boiling, heat is required. In slow evaporation the water takes this heat from the object with which it is in contact.

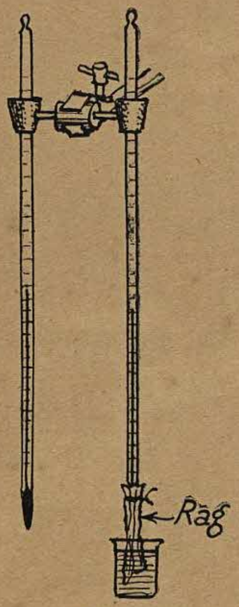


FIG. 33
Wet and Dry Bulb Thermometers

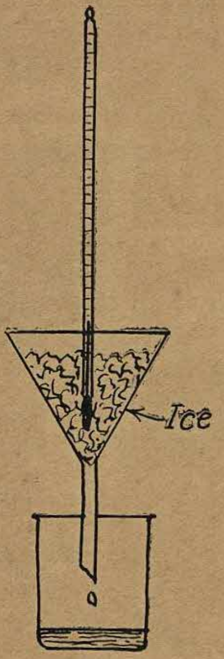


FIG. 34
Demonstrating the Freezing-Point of Water

EXPERIMENT. Fit up two thermometers side by side as Fig. 33. Round the bulb of one of them tie a piece of rag soaked in, and dipping into, water. Put the thermometers in a draughty place, or better still blow a cold draught upon them from a pair of bellows. Note the temperatures recorded by each thermometer. This experiment works more effectively if methylated spirit is used instead of water to moisten the rag.

Exercises. (*a*) Where is the heat coming from to evaporate the liquid on the rag?

(*b*) Why do our wet hands feel cold after washing, especially in a wind?

(*c*) Why is ice covered with a wet rag to keep it from melting?

(*d*) Why do some butter coolers have a wet flannel cover?

The extent to which water will evaporate from a wet rag depends upon the amount of water vapour in the air, and this varies from time to time with the weather. Thus a pair of thermometers such as those in Fig. 33 will indicate the amount of water vapour in the air. If there is much, the "wet bulb" thermometer will lose little heat because little evaporation can go on, consequently its temperature will not be much lower than that of the dry bulb. If the air is dry there will be much evaporation, and so the wet bulb will show a much lower temperature than the dry bulb. Such an instrument, used for weather study, is called a "Hygrometer."

Water and Ice

EXPERIMENT. Apparatus as Fig. 34. Stir the ice occasionally.

(*a*) What is the temperature of the melting ice (Fahrenheit)?

(*b*) What is the temperature of the melting ice (Centigrade)?

This temperature is known as the *Freezing-Point* of the water.

CAN WE LOWER THE FREEZING-POINT OF WATER?

EXPERIMENT. Put some crushed ice in a beaker, and take its temperature. Now add some powdered salt; stir well, and again take the temperature. Add more salt until the lowest possible temperature has been reached. You have made a "freezing mixture" such as is used in ice cream freezers.

WHY DO PIPES BURST WHEN THE WATER IN THEM FREEZES?

EXPERIMENT. Prepare a freezing mixture as in the last experiment. Fill a small (2-in.) test tube full of water, and cork it tightly. Put the test tube in the freezing mixture, and stir the mixture well until the water in the tube has frozen solid.

(*a*) What happens to the test tube? Why?

(*b*) Can you now explain why a water pipe is liable to be split open when the water in it freezes? Why are "burst pipes" not detected until a thaw sets in?

V. AIR, WATER, AND WORK: ATMOSPHERIC PRESSURE

Has Air any Weight?

Experiment. Fit up a round-bottomed flask with a cycle valve (Fig. 35) and see that all joints are tight—if necessary stop joints with plasticine. Balance the flask as shown, using sand for a counterweight. Carefully unhook the flask and pump as much air into it as you can with a cycle pump. Hang the flask once again on your "balance."

(*a*) Is the flask heavier than before?

(*b*) How do you account for any change in weight?

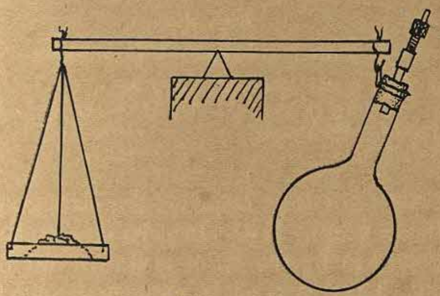


Fig. 35
Weighing Air
(*The cork should be held in with wire.*)

Experiment. Using a similar flask, but fitted with a pinchcock instead of a valve, pump as much air *out* of the flask as you can with an air pump; close the cock and balance the flask as before. Now remove flask and open the cock; after a few moments hang again on balance.

(*a*) Is the flask heavier than at first?

(*b*) How do you account for any change in weight?

Air Presses in All Directions

From these experiments we have learned not only that air has weight, but also that the air around us exerts a *pressure*. For if not, why should it rush into the flask in the second experiment? We can show, by a few simple experiments, that the *atmosphere*—the air in which we live—exerts a pressure in all directions.

Experiment. Cover the end of a funnel with a sheet of thin rubber (Fig. 36). Put the end of the funnel in your mouth, and suck the air from inside it.

(*a*) What happens to the rubber?

(*b*) Does it make any difference if the funnel points upward, downward, or sideways?

Experiment. Use a glass syringe (Fig. 37) as shown. When the piston is drawn up, why does the water enter the syringe?

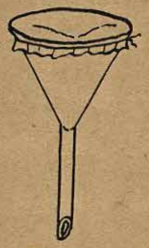


Fig. 36
Funnel for Air Pressure Experiment

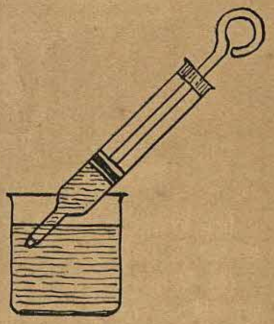


Fig. 37
Demonstrating Air Pressure with a Syringe

Experiment. Cork tightly a small bottle (which is full of air), and place it under the receiver of an air pump. Pump the air from the receiver. What happens to the cork? Can you account for this?

Experiment. Fix a small toy balloon inside an air-pump receiver, with a tube leading from it to the outer air (Fig. 38). When you pump the air from the receiver the balloon expands and may burst. What is causing it to do this?

Experiment. Obtain a thin-walled tin can with a neck (Fig. 39). Special cans can be used for this, but the experiment will work well with a motor-oil can. Put a little water in the can and boil it over a flame. When the water is boiling vigorously, cork the can tightly, *at the same time removing the flame.* When the tin cools it collapses.

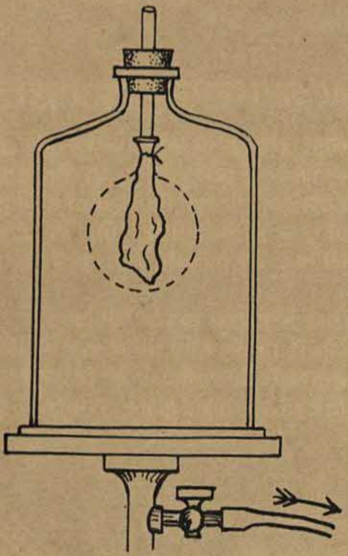


FIG. 38

Experiment with Pump Receiver

(*a*) What substance fills the can when the water is boiling?

(*b*) What happens to this when the can cools: why does the can collapse?

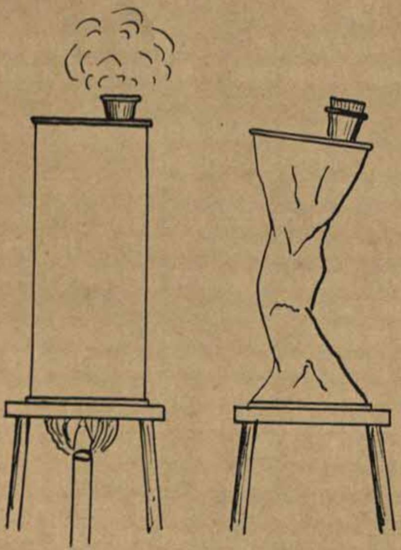


FIG. 39

The Collapsing Can

Changes in Air Pressure: The Barometer

Atmospheric pressure changes slightly from day to day according to the weather. We cannot detect these changes, which are very small, unless we have a special instrument called a *Barometer,* which is used for weather study.

THE "LIQUID-LESS" OR ANEROID BAROMETER

A section of this is shown in Fig. 40. The thin metal box is exhausted of air, and would collapse if it were not kept open by the strong spring. As the atmospheric pressure changes, so the box is pressed in by the air or is drawn out by the spring. These very slight movements are transmitted to the pointer on the dial by means of levers and a fine cord or chain, in such a way that a tiny movement of the box causes a large movement of the pointer.

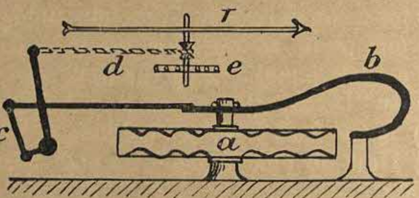


FIG. 40

Section of an Aneroid Barometer

(*a*) *Thin metal box exhausted of air.*
(*b*) *Strong spring.*
(*c*) *Levers.*
(*d*) *Chain.*
(*e*) *Hair-spring to keep chain tight.*
(*f*) *Pointer.*

THE LIQUID, OR MERCURY, BAROMETER

EXPERIMENT. Fill a test tube with water, put your thumb over it, and invert it into a beaker of water (Fig. 41). Why does the water stay up in the tube?

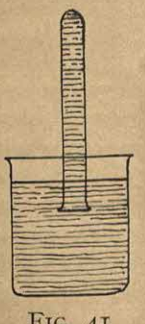


FIG. 41

Tube of Water inverted in Water

You could go on doing this with longer tubes until they were too large to handle, and still the atmospheric pressure would be enough to hold up the water in them. Long ago scientists found that the air pressure will hold up a column of water about 33 ft. high.

The liquid metal, mercury, is more than 13 times as heavy as water, and so we may expect that the atmospheric pressure will support a column only about one-thirteenth as high, i.e. about 30 in., or 76 centimetres.

EXPERIMENT. Repeat the last experiment, using a tube about 33 in. long, and using mercury instead of water (Fig. 42). You now find that, however many times you do it, the atmospheric pressure will support a column of only about 30 in. high. The exact height of the column depends upon the weather; if the air is dry the pressure will be rather greater than if the air is damp.

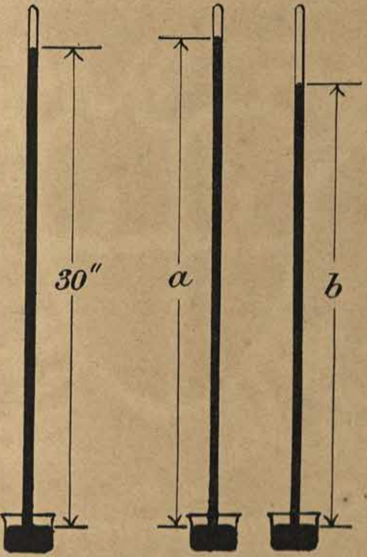


FIG. 42

The Mercury Column

(*a*) *Barometer in dry air.* (*b*) *Barometer in damp air.*

Accurate barometers are made exactly in this way, the height of the column being measured to estimate the air pressure. For household use, however, the instrument is altered slightly so as to give a direct reading on a dial. A diagram of a "wheel" pattern barometer is shown in Fig. 43.

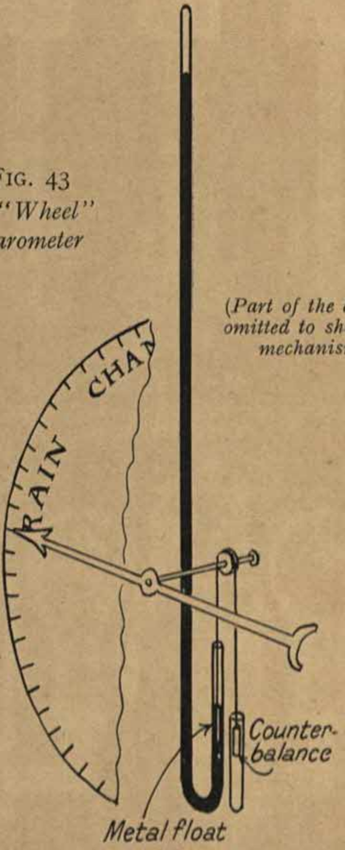
Making Air Pressure do Work: Pumps

A *Lift Pump* is shown in Fig. 44. When the piston is raised the air pressure forces the water from the well up into the cylinder. It cannot pass back again because of the valve. When the piston is lowered the water passes through the valve in the piston, into the space above it. Next time the piston is raised the water flows out through the spout.

If it were possible to make such a pump perfectly, without the slightest leakage, it would raise water about 33 ft.—the maximum height of water which the atmospheric pressure will support—but in practice it is not possible to make a lift pump to raise water more than about 25 ft. If water is to be pumped to a greater height than this, a *Force Pump* (Fig. 45) must be used.

FIG. 43

A "Wheel" Barometer



(*Part of the dial is omitted to show the mechanism.*)

In this pump, the water, after being raised into the cylinder by atmospheric pressure, does not pass through the piston, but remains in the cylinder. When the piston is forced down by the next stroke, the water is forced out to a height

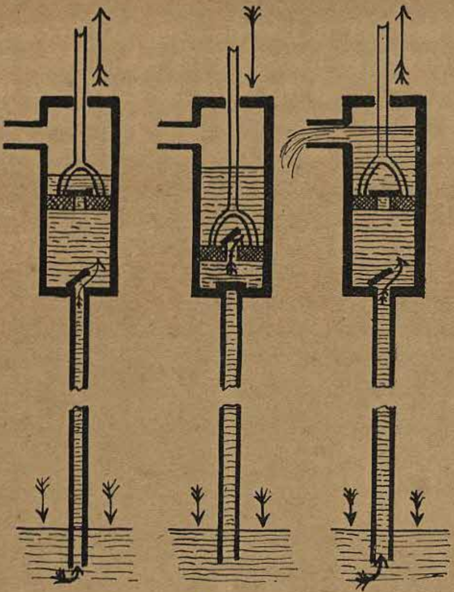


FIG. 44

A Lift Pump

The three sections show successive up, down, and up strokes of the piston.

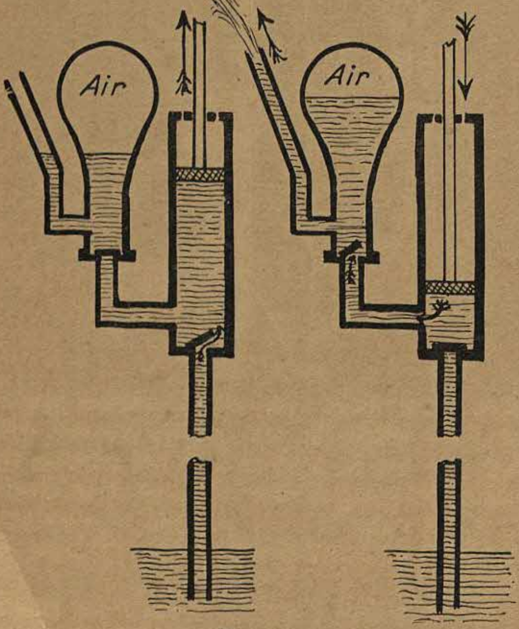


FIG. 45

A Force Pump

The two sections show successive up and down strokes of the piston.

which depends on the pressure put on the piston. Air, in a closed chamber connected to the outlet pipe, acts as a spring when compressed by the water, and keeps the pressure of the outgoing water constant. This kind of pump is used in fire engines, and in many other situations where it is necessary to force water to a great height.

THE HEART AS A PUMP

The heart is the most important of all pumps (Fig. 46). It consists of four chambers, of which the upper two, which receive the blood, are called the *auricles*, and the lower two, which send out the blood, the *ventricles*. When the heart expands, the auricles fill with blood from the veins and the lungs. The auricles then contract, forcing the blood through the valves into the ventricles. The ventricles then contract, driving the blood through more valves into the arteries.

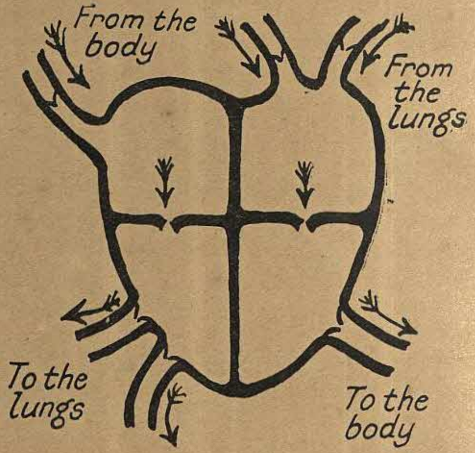


FIG. 46

Section of the Heart

THE VACUUM CLEANER

Atmospheric pressure is used in our homes for cleaning purposes. We say that a vacuum cleaner "sucks up" the dirt, but what actually happens is that the air is removed from the container by the fan (Fig. 47), and into this space rushes the air from under the carpet, carrying with it the dust from the carpet. The dust is kept from passing on to the fan by the bag of fine material which acts as a filter for the air.

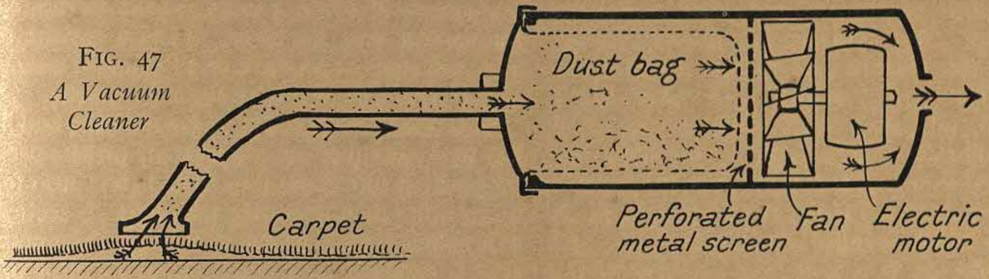


FIG. 47
A Vacuum Cleaner

COMPRESSED AIR

Air compressed to a higher pressure than that of the atmosphere serves many useful purposes. It is used in the "pneumatic" (air filled) tyres of cycles and motors, where it serves as a cushion to soften the shocks caused by the wheels bumping on the road. It is used to drive compressed air engines, which work very much like steam engines, in places such as mines, where steam or petrol engines could not be used because of the fumes. It is used to operate tools such as riveting hammers, engineer's drills, rock drills, and those borers which make such a deafening noise when roads are being broken up in large towns.

Compressed air is also used to work the "Westinghouse" brakes on a railway train.

Water Pressure: The Hydraulic Press

EXPERIMENT. Fit up the apparatus shown in Fig. 48. The two tubes are fitted with cork pistons, round which are wound cotton thread, to make them fit well. Into each piston is

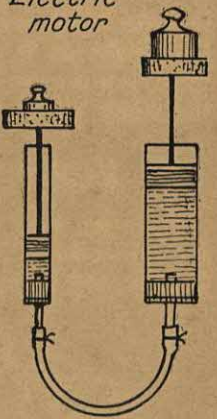
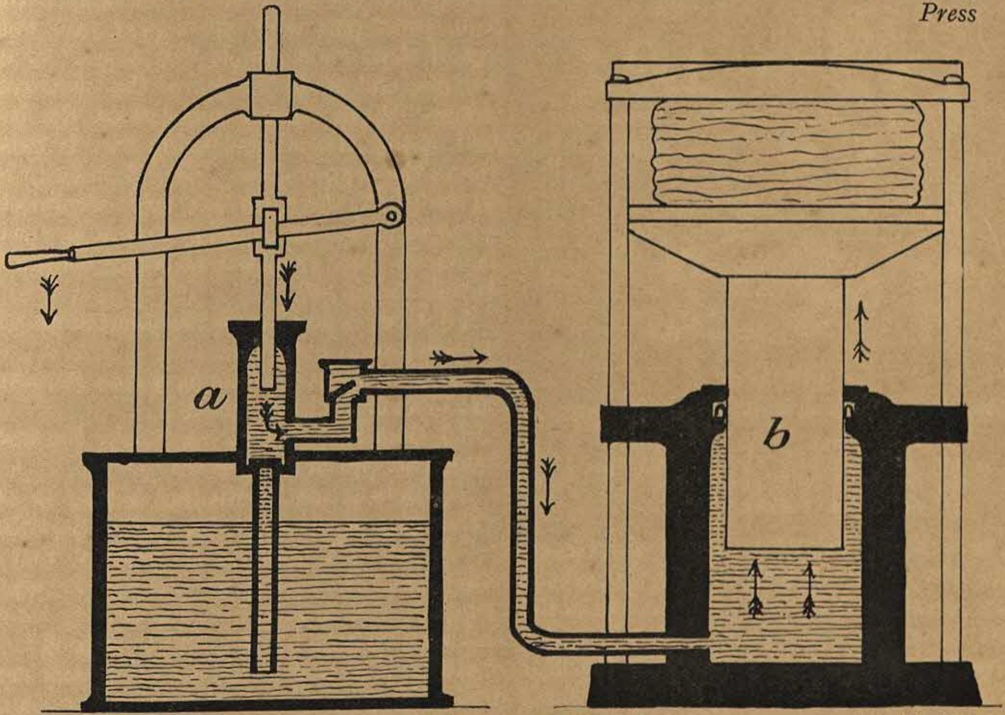


FIG. 48
A Model Hydraulic Press



(a) Pump FIG. 49. *A Hydraulic Baling Press* *(b) Ram*

fixed a length of stiff wire, with a wide cork bung at the top. The connecting tube must be strong, and all joints must be made leak-proof with plasticine. The "press" is filled with water, and it will be found that a small weight on the small piston will raise a large weight on the other one.

The action of the press depends on the *pressure* of the water, which is the same throughout. If the area of the smaller piston is 1 sq. in., and the weight on it is 4 oz., the pressure of the water is 4 oz. per square inch. If the area of the larger piston is 4 sq. in., then the total pressure on it will be 4 times as great as that on the smaller one, i.e. 16 oz. Thus a weight of 4 oz. will support a weight of 1 lb., and a weight of just over 4 oz. will raise the 1 lb. weight.

This principle is used in hydraulic lifts, and in the hydraulic (i.e. water-operated) presses used for packing soft goods into tight bales; also for many other manufacturing purposes. A section of a baling press is shown in Fig. 49. The pressure is supplied by a small pump to raise the ram; when the ram is to be lowered again the water is released through a tap.

VI. ELECTRIC CURRENTS—HOW A FLASH-LAMP WORKS

There are several ways in which electricity shows its effects: for instance, in lightning and thunder; and in the curious behaviour of objects such as amber or glass when rubbed with certain fabrics. For many years these things have been known and studied, but not until the uses of the *electric current* became known was electricity regarded as anything but a curiosity. The most important applications of electricity are those of the electric current, and there are many familiar things involving its use which we can study.

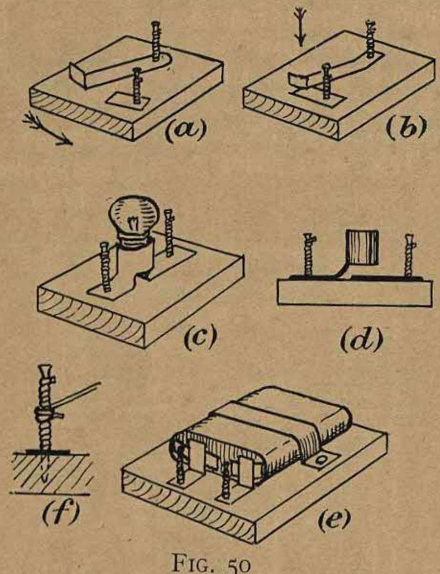


FIG. 50

Simple Home-made Electrical Appliances

(a) Lever switch. (b) Press switch.
(c), (d) Lamp-holder for flash-lamp bulb.
(e) Holder for flash-lamp battery.
(f) Panel pin "terminal."

The Electric Circuit

We know that most electrical devices are connected by wires. Are there any rules to be observed in making these connections?

EXPERIMENT. With thin tinplate make a switch, lamp-holder and battery holder as shown in Fig. 50. Use an ordinary flash-lamp battery. 1-in. panel pins with *bare* copper wire wound round them make simple "terminals" or connectors, and avoid the use of the more costly screws. When making connections the bared end of the covered connecting wire is twisted round the copper spiral. Fix a flash-lamp bulb in the holder, and try various ways of connecting so as to make the lamp light when the switch is closed. Any arrangement which will do this is called a *Circuit.*

(*a*) Draw a diagram of the connections when satisfactory.

(*b*) How many connecting points (terminals) are there on each instrument?

(*c*) Does it matter in what order the instruments are put in the circuit?

(*d*) Does it matter whether a long or short connecting wire is used in any part of the circuit?

You can see from this experiment that the circuit must be *continuous*—i.e. that the current must be able to pass from the battery through each instrument in turn, and then back to the battery. The switch is just a convenient means of breaking the circuit without disconnecting the wires.

Short Circuits

Experiment. Connect circuit as in last experiment, then try the effect of connecting a wire directly across each instrument, the switch, lamp, and battery, in turn (Fig. 51). Connect a wire across the battery only for a moment or you will spoil it. Close the switch each time to see if the lamp will light.

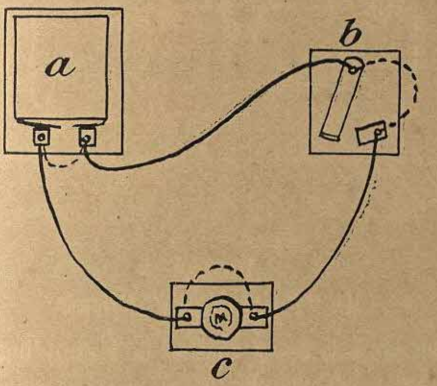


Fig. 51

Short Circuits

(*a*) *Battery.* (*b*) *Switch.* (*c*) *Lamp-holder.*
The dotted lines show "short-circuit" wires.

(*a*) What happens in the circuit when a wire is connected across the switch?

(*b*) What happens in the circuit when a wire is connected across the lamp?

(*c*) What happens in the circuit when a wire is connected across the battery?

The effect of connecting a wire across an instrument is to *short-circuit* it—i.e. to make an easy path so that the current can rush through the wire instead of going through the instrument and making it do its proper work. Short-circuiting a switch merely makes a permanent connection so that the lamp is always lighted. Short circuits must be avoided in all electrical arrangements, and will do serious damage to a battery. (*N.B. Never* short-circuit an accumulator.)

Good and Bad Conductors of Electricity

Will any substance serve to carry an electric current?

Experiment. Connect up circuit as for first experiment, and try the effect of including various materials as part of the connections (Fig. 52). Note results as follows: If the circuit works well write "current passes"; if not, write "current does not pass."

Iron Wire ....
Brass Wire ....
Tinplate strip.........
Knife blade ....
Cardboard or paper ...
Wood ....
Carbon rod ....
Glass rod ....
String ....
Indiarubber ....

What kind of substance will carry the current readily? Such substances are called *good conductors* of electricity. Other substances conduct badly (in this experiment they will cause the lamp to give only a very feeble light); other substances conduct electricity practically not at all. These last are called *Insulators*.

Exercise. (*a*) Why are electric connecting wires usually covered with cotton, silk, rubber, or wax?

(*b*) Why is an ebonite or dry wood panel used in a wireless set, and not a metal panel?

(*c*) When a switch is open, air lies between the metal parts. Is air a conductor or an insulator?

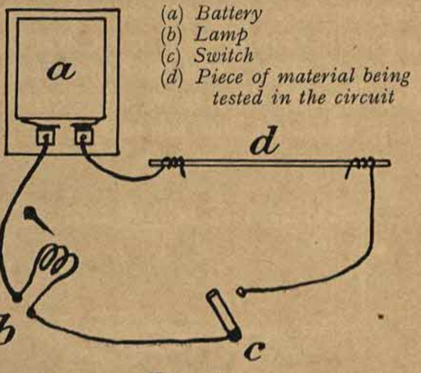


Fig. 52

Testing "Conductors" of Electricity

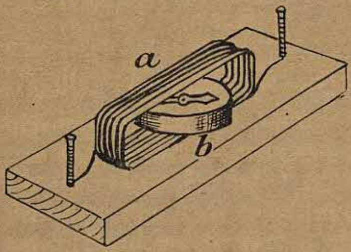
(*d*) Why is it not necessary to use covered wires on telegraph poles?

Will a Current Pass through Water?

Experiment. For this experiment use a *galvanometer*, which will detect a current much smaller than that needed to light a lamp. A simple home-made galvanometer is shown in Fig. 53. Try to make the current pass through a drop of tap water, salt water, and water with a little vinegar, lemon-juice, or other *acid*, in it, in turn (Fig. 54). Note results as before.

Tap water ..... Salt water ..... Acid water .....

From this we see that a very small current will pass through salt or acid water, but none that we can detect through tap water. Actually, as we know, no water is really pure unless it has been distilled, and a much stronger electric force than is given by our small battery *will* drive current through tap water.



(a) Coil of No. 28 Cotton-covered wire
(b) Small magnetic compass

FIG. 53
A Home-made Galvanometer

Exercise. Why must all electric circuits and apparatus be kept dry?

The Earth a Conductor of Electricity

EXPERIMENT. Connect galvanometer and battery as shown (Fig. 55), with two clean knitting needles or stiff wires thrust into the earth about 2 yd. apart. Will the current pass?

Exercise. (*a*) Why must all electric circuits be kept insulated from the earth?

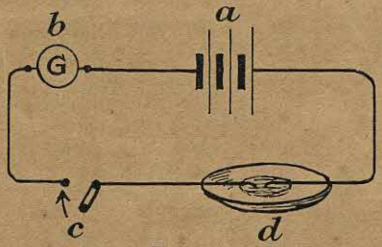


FIG. 54
Current passing through Liquids

(*a*) *Battery.* (*b*) *Galvanometer.* (*c*) *Switch.*
(*d*) *Ends of wire dipping into drop of liquid in a watchglass.*

(*b*) Why are the bare wires on telegraph poles connected to cup-shaped insulators which are made to throw off the rain-water?

In the comparatively high-pressure circuits used for house lighting and heating, great care has to be taken to prevent the current leaking away to earth. If a person touches a "live wire," or a "live" part of a switch or other instrument, the current will pass through his body to the earth, and give him a shock. The strength of the shock depends upon whether he is standing on a good or a bad conductor.

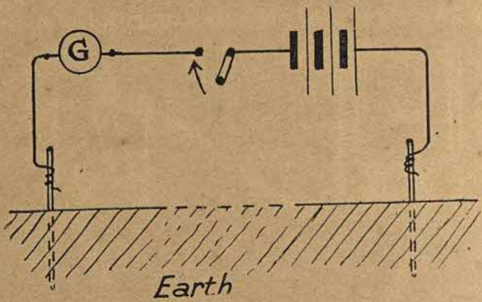


FIG. 55
An "Earth Return" Circuit

Exercise. (*a*) A person touches a "live wire" (i) when standing on a dry wooden floor; (ii) on a damp brick floor. In which place will he get the stronger shock, and why?

(*b*) Why is it dangerous for a person in a bath to touch any part of an electrical lighting or heating circuit?

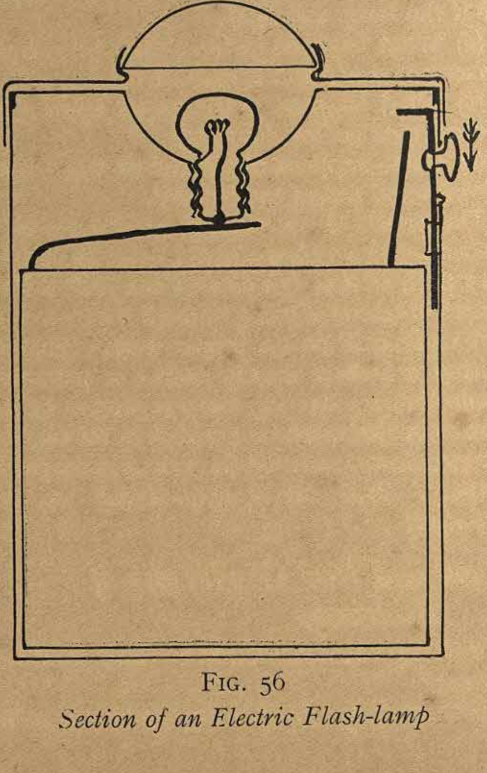


FIG. 56
Section of an Electric Flash-lamp

The Circuit in a Flash-lamp

Fig. 56 shows a section of a flash-lamp. The tinplate case forms part of the circuit: the current passes from the battery to the centre of the lamp bulb; through the bulb filament to the screw casing; thence through the metal case to the switch; and, when the switch is pressed, back to the battery.

The Voltage of a Flash-lamp Battery

Experiment. Connect a flash-lamp battery as shown (Fig. 57) to a *Voltmeter*, which is an instrument for measuring electrical *pressure* (or *Electro-motive Force:* E.M.F.). Note the reading of the voltmeter. This is the *Voltage* of the battery. Electric bulbs vary according to the voltage which is required to light them; for the ordinary flash-lamp battery a 3·5-volt bulb is necessary.

Experiment. With a 3·5-volt flash-lamp battery, test the light given with a 2-volt bulb (leave on only for a moment); a 6-volt bulb; and a 12-volt bulb. You will see that the low voltage bulb gives a very brilliant light (and will soon "burn out")—whereas the higher voltage bulbs give a very feeble light.

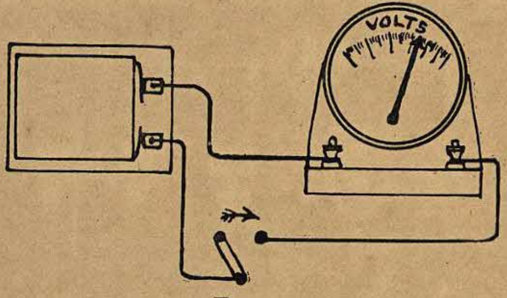


Fig. 57

Finding the Voltage of a Battery

VII. MORE ABOUT ELECTRIC LIGHTING CIRCUITS

Few electric circuits are so simple as that of a flash-lamp; for in lighting a house we have many lamps and switches, all working from one source of electric pressure—the "mains"—while such things as electric advertisement signs and traffic control signals may contain very complicated circuits. All these circuits, however, work on similar principles to the simple circuit we have already studied.

The Current Passing from a Cell: Series Wiring

Experiment. Connect circuit as shown in Fig. 58 (i) with one 3·5-volt bulb; (ii) with two; (iii) with three. The *Ammeter* records the *amount of current* passing, in *amperes* (amps.). (*N.B. Never* connect an ammeter direct to a battery without at least one lamp in circuit with it. The ammeter is a delicate instrument which can easily be damaged if too strong a current is passed through it. By connecting a lamp in series with the ammeter this risk is avoided. The voltmeter, on the other hand, is less delicate, and may be connected directly with a battery without damage.) Note results as under.

Using 1 lamp: Volts...... Amps.........
,, 2 lamps: Volts...... Amps.........
,, 3 lamps: Volts...... Amps.........

(*a*) Does the number of lamps (the "*load*") noticeably alter the E.M.F. of the battery as given by the Voltmeter reading?

(*b*) Does the number of lamps alter the amount

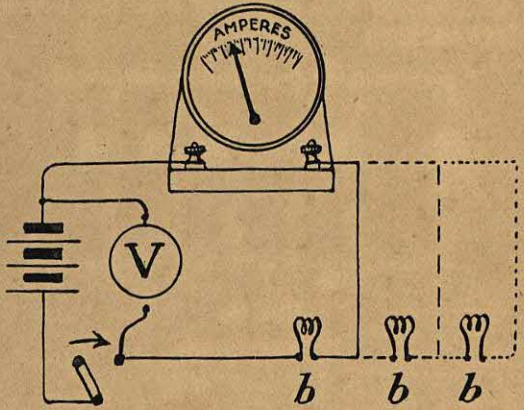


Fig. 58

Series Wiring

V = voltmeter.
b, b, b.—lamp bulbs.

——— *Connection for 1 bulb.*
– – – ,, ,, *2 bulbs.*
...... ,, ,, 3 ,,

of current passing as given by the Ammeter reading? If so, in what way?

Lamps or other instruments connected in this way, so that the current passes successively through one after the other, are said to be connected *in Series*, and we see that the effect of adding lamps in series is to cut down the current and so the light.

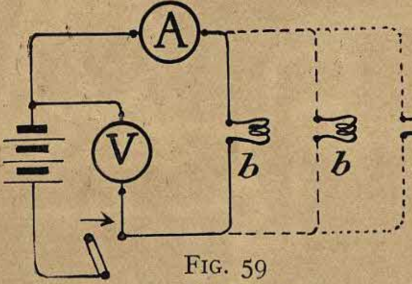


FIG. 59

Parallel Wiring

V. voltmeter. A. ammeter. b, b, b. lamp bulbs.

How can we connect several lamps to the one battery so that each will shine brightly?

Parallel Wiring

EXPERIMENT. Connect the circuit as Fig. 59, first with one lamp, then with two, and then with three. Note results as under—

Using 1 lamp: Volts ...... Amps.........
,, 2 lamps: Volts ...... Amps.........
,, 3 lamps: Volts ...... Amps.........

(*a*) Does the load noticeably alter the E.M.F. of the battery?

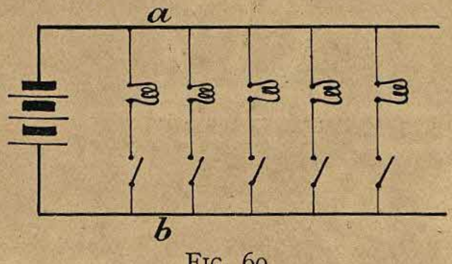


FIG. 60

Wiring Circuit

(a, b) "Feeder" wires.

(*b*) Does the number of lamps alter the amount of current passing? If so, in what way?

(*c*) Does each lamp shine brightly when switch is pressed?

Lamps or other instruments connected in this way, so that the current can divide up and pass through each branch at the same time, are said to be connected "*in parallel*." This is the method adopted in houses for lighting and heating circuits.

EXPERIMENT. Connect a circuit as shown in Fig. 60, including as many lamps as you wish, each with its own switch, connected from one "feeder" wire to the other. Any or all of the lamps can be lighted by closing the right switches, as in house wiring. You may make this experiment more interesting by wiring a model house—a box divided into "rooms" or a dolls' house—in this way.

The Resistance of a Circuit

You have seen from the last two experiments that while the *pressure* (the E.M.F.) of the supply remains practically the same whatever the load, the *current* passing depends upon the nature of the circuit.

If the circuit contains several lamps in series these offer a considerable *resistance* to the passage of the electricity, and so the current which passes is small. On the other hand, if, as in parallel wiring, we provide several easy paths for the current to follow, the circuit offers less resistance, and so the current is greater.

The Rule for Current and Resistance

If we are using the same supply each time (the same E.M.F.) we may say that *the greater the resistance of the circuit, the less the current that passes in it.*

If, therefore, we connect the terminals of a battery with a low resistance (a copper wire, or several lamps in parallel) we shall be taking a great deal of current from the battery.

"*Running Down*" *a Battery*

You may have noticed that with three or more lamps in parallel connected to a flash-lamp battery the light soon became dim, especially if the battery was an old one. This small battery will not deliver the large amount of current required for very long. If we wish it to last longer, we must increase its size by adding more batteries. But we do not want to increase its E.M.F. or we shall "burn out" the bulbs.

Batteries in Series and Parallel

Experiment. Measure the E.M.F. of each of three flash-lamp batteries separately, as in a previous experiment. Now connect two of them, and then three, *in series*, as Fig. 61*a*, and measure the total E.M.F. Then connect the batteries *in parallel*, as Fig. 61*b*. This time all the positive poles are connected, and a wire is taken from them to one side of the voltmeter, and similarly with all the negative poles. Note results as follows—

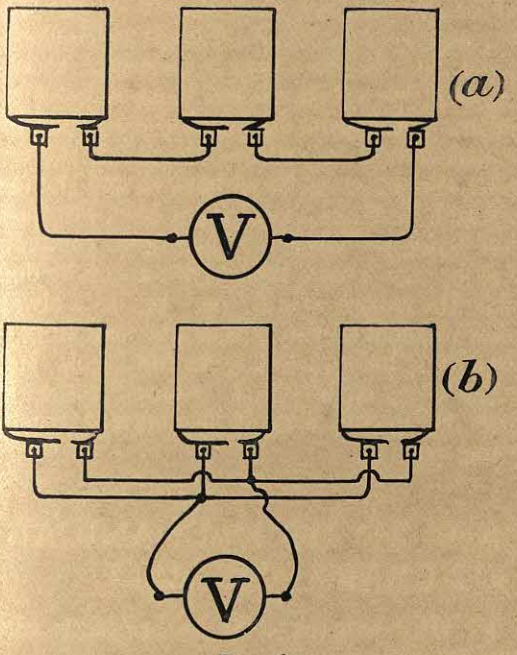


Fig. 61

Batteries in Series and in Parallel

1 cell: E.M.F. . . . V.
2 cells. Series E.M.F. . . . V. Parallel E.M.F. . . . V.
3 cells. Series E.M.F. . . . V. Parallel E.M.F. . . . V.

By connecting batteries in series we add their E.M.F.'s, getting a battery of higher pressure, but one that will last no longer than a single one. But if batteries are connected in parallel, we do not noticeably increase the E.M.F.—we do, however, get a battery that will last two or three times as long as a single one with the same output of current.

Exercise. (*a*) For a model house circuit with several 3·5-volt bulbs in parallel, you have six flash-lamp batteries available. Will you connect the batteries in series or parallel?

(*b*) For another circuit you have 6-volt bulbs, but only 3·5-volt batteries. How will you connect the batteries?

House Wiring Circuits

Much higher voltages than those obtained from a small battery are generally used for house lighting. In most towns the supply is at a pressure of 210, 220, or 230 volts.

This pressure (voltage) will send a large current through a fairly high resistance such as the human body, and may give a serious shock, so that house circuits must always be handled with caution. If by accident there is a short circuit in house wiring—e.g. if two wires come into contact in a lampholder—or if we load too many lamps in parallel on to one circuit, too much current passes for the thin copper wires to carry, and if not protected they would get hot, and perhaps set fire to the house. This risk is avoided by having on each separate circuit a "safety valve" device known as a *Fuse*.

The Electric Fuse

Experiment. Connect about 2 in. of 2-amp. fuse wire (i.e. thin lead wire which will melt if a current of 2 amp. is passed through it) across two nails, as shown in Fig. 62. From the nails run wires to a switch and to two flash-lamp

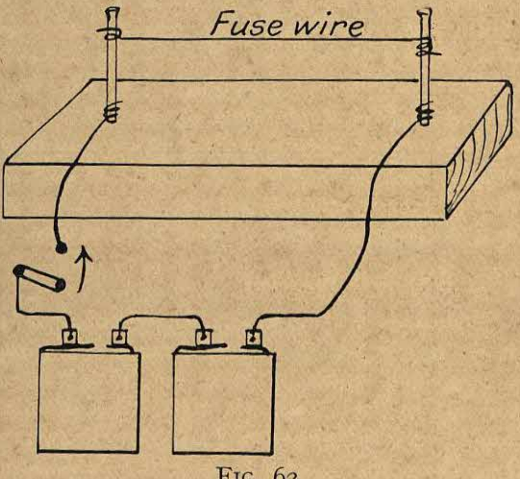
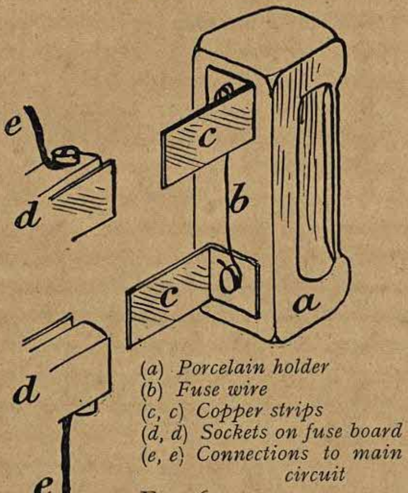


Fig. 62

Fuse Wire Experiment

batteries connected in series. When you close the switch what happens to the wire?



(*a*) *Porcelain holder*
(*b*) *Fuse wire*
(*c, c*) *Copper strips*
(*d, d*) *Sockets on fuse board*
(*e, e*) *Connections to main circuit*

FIG. 63

An Electric Fuse

Repeat the experiment with a piece of very thin copper wire (e.g. one strand from a piece of "flex" wire). Does this wire fuse? If not, can you explain why?

In every house wired for electric light there is a *Fuse Box* in which short lengths of fuse wire are placed in every circuit. A single fuse is shown in Fig. 63. The fuse wire is connected to two copper strips which project from a porcelain holder. These strips fit into sockets which are connected in series with the circuit. If the fuse melts, the holder can be withdrawn and the fuse replaced. The block is then put back into position, when the circuit is once more complete. If great care is used, this operation can be done while the current is still "on," but it is always wiser to avoid all risk of shock by switching off the current before handling the fuse block. Most house wiring circuits have "5-amp." fuses—i.e. fuses which will melt if the current reaches 5 amperes.

VIII. HOW ELECTRICITY IS MADE TO DO MECHANICAL WORK: THE ELECTRIC TELEGRAPH AND BELL

Not only is the electric current useful for lighting and heating, but it also does a great deal of mechanical work in the modern world. It drives trains and trams, and operates all kinds of machinery in factories. We are not, however, ready to study the electric motors, used for these purposes, which *rotate* (turn an axle round) until we understand how electricity can perform the simpler task of moving an object *to and fro*. This it does in the familiar electric bell, in the electric telegraph, and in other mechanisms.

The Electro-magnet

EXPERIMENT. Make an electro-magnet as shown in Fig. 64. It is a short piece of soft iron (a large nail which has been heated to redness and allowed to cool will serve the purpose) round which is first wrapped a piece of dry paper. Over the paper is wound a spiral of fine cotton-covered (insulated) copper wire. Connect up the magnet as shown to a flash-lamp battery and a spring press switch. Place the end of the electro-magnet over and close to a pile of small nails or iron filings, and press the switch.

(*a*) What happens to the nails or filings when the switch is pressed?

(*b*) What happens to the nails or filings when the switch is opened again?

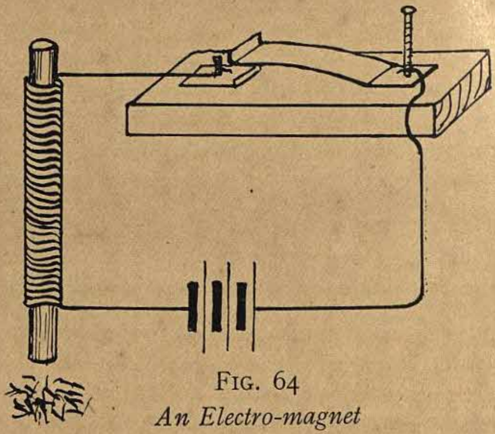


FIG. 64

An Electro-magnet

To make a stronger electro-magnet we must use many turns of wire wound in layers on a bobbin. The principle of the electro-magnet is applied in electro-magnetic cranes, which will pick up large quantities of scrap iron that would otherwise be very difficult to handle, and which will drop them again where required.

EXPERIMENT. A model electro-magnetic crane can be made as Fig. 65. The bobbin is made from cardboard fixed together with seccotine, and wound with several layers of No. 26 or No. 28 cotton-covered wire. Such a crane, operated by a flash-lamp battery, will pick up a quantity of small nails or scraps of iron.

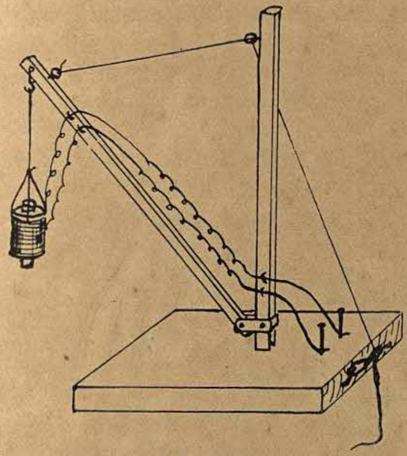


FIG. 65
A Model Electro-magnetic Crane

WILL STEEL DO AS WELL AS SOFT IRON FOR AN ELECTRO-MAGNET?

EXPERIMENT. Make an electro-magnet as in the first experiment, but use a piece of steel knitting-needle for the core. Try to pick up iron filings with it.

(*a*) What happens to the filings when the switch is closed?

(*b*) What happens to the filings when the switch is opened again?

We see from this that if an electro-magnet is to lose practically all its magnetism when the current is switched off (and in this form it is generally most useful) its centre (or "*core*") must be made of soft iron and not of steel.

How is an Electro-magnet Made to Move Something to and fro?

THE TELEGRAPH SOUNDER

EXPERIMENT. Make a simple telegraph sounder as shown in Fig. 66*a*. The electro-magnet, with the wound bobbin, is made as for the crane. The tinplate "*armature*" (the moving part) must be so adjusted as to be about $\frac{1}{16}$ in. above the end of the magnet. When the sounder is connected to a "tapping key" (a press-down switch) and battery as shown in Fig. 66*b*, the armature is drawn down by the electro-magnet till it touches the upright piece of tinplate and makes a tapping sound. When the switch is opened again, the armature springs back into its original position. Thus the taps of the key are reproduced in the sounder. The wire between key and sounder may be very long—some electric telegraphs working on this principle operate through wires hundreds of miles long. Only one wire need be used to connect the two—the return circuit may be through the earth (Fig. 66*c*). (See also Section VI.—"Earth circuits.") The method of signalling from one end of the wire to the other is by means of the

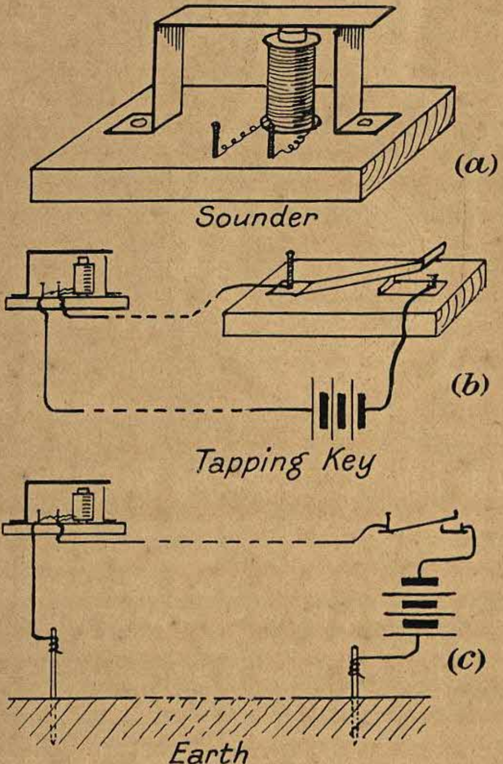


FIG. 66
A Model Telegraph Sounder

Morse Code—a system in which each letter of the alphabet is represented by a group of long or short taps ("dashes" or "dots") or of both combined. Thus the letter A is "dot-dash"; the letter B "dash-dot-dot-dot"; the letter C "dash-dot-dash-dot;" and so on.

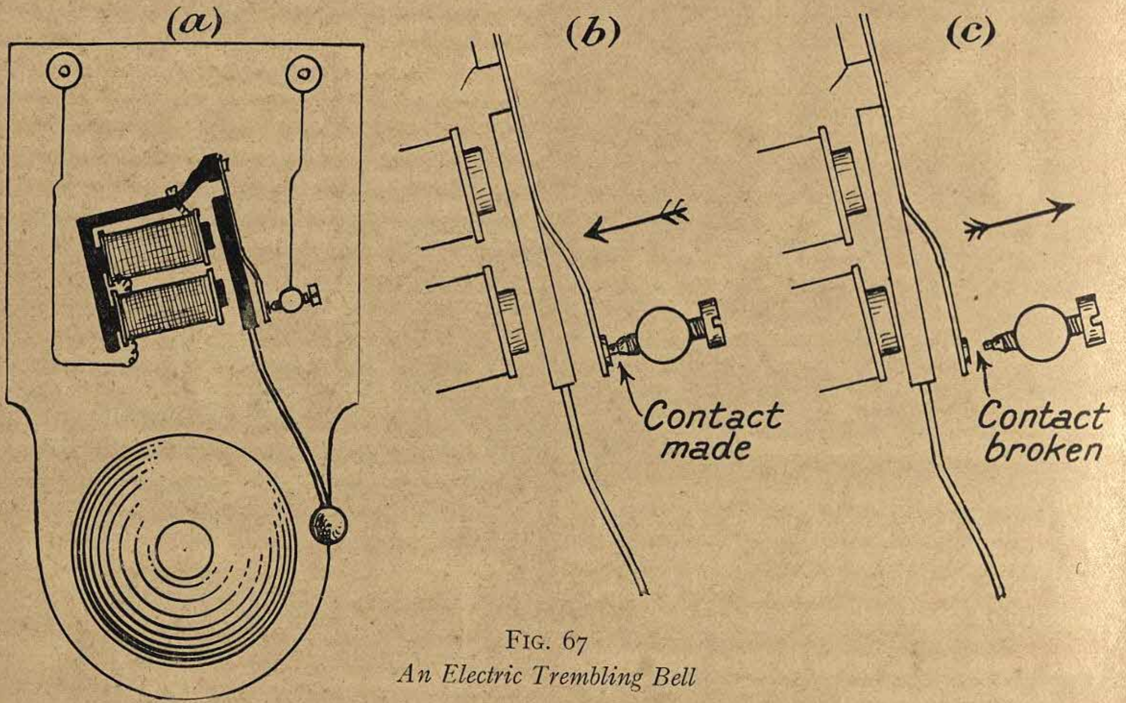


FIG. 67
An Electric Trembling Bell

The Electric Trembling Bell

When we press the bell push at the door of a house the bell keeps on ringing as long as the switch (the bell push) is closed, and the hammer of the bell does not merely make one stroke, as it would if the bell were like a sounder. Instead it continues to move rapidly to and fro—to "tremble." This effect is obtained by a device called the "*contact breaker.*"

Fig. 67*a* shows an electric bell. The current passes from one terminal through the coils of the electro-magnet to the contact spring, then through the contact-breaker and back to the other terminal, and so to the battery and switch. Directly the current passes the electro-magnet draws the armature to it, causing the hammer to strike the bell (Fig. 67*b*). But as it does this it causes the contact-breaker to open, thus breaking the circuit. Directly this happens the electro-magnet loses its magnetism (67*c*) and allows the spring to carry the armature, with hammer attached, back to its first position. Then the whole action is repeated, and this may go on many times in a second, causing the familiar "trembling" effect of the bell. The contact breaker is adjusted by means of the screw —if the screw is too far out the contact-breaker will not "make," i.e. no current will pass and the bell will fail to ring. If it is screwed up too tightly the contact-breaker will not "break," and the bell will act as a sounder, the hammer giving one stroke only when the switch is pressed. The contact-breaker is therefore sometimes called the "Make-and-Break."

THE BUZZER

If the bell and hammer are removed, the armature will oscillate (move to and fro) with a buzzing sound. This is the principle of the buzzer sometimes used in houses and offices instead of a bell, and also used for army signalling. The electric motor horn works in much the same way.

BIOLOGY

The Senior School Child and his Needs

An educational problem of the first magnitude presented itself with the reorganization of primary education and the consequent establishment of the Senior School. The solution of the problem in the best interests of the children themselves implies a responsibility which is all the greater as so large a proportion of the population is directly or indirectly affected by it.

The Senior School is for its administrators and teachers a new region of endeavour. There is no precedent for their activity in the history of education and, like pioneers in other walks of life, they are even now at one time tasting the bitterness of failure and at another they are experiencing the exhilaration of success. In the course of time they will arrive at principles and rules of conduct forged out of strenuous, intelligent experience and critical survey, but this course of time must of necessity extend far into the future.

Meanwhile certain definite facts stand out in bold relief. Children of marked intellectual ability have at the age of 11 plus passed on to Secondary and Central Schools. The children who are left constitute the Senior School. Those teachers who are treating the children, however sympathetically and kindly, as of inferior mentality, needing infinite patience, very little knowledge of facts and much repetition and memorizing, will contribute little to the happiness and efficiency of the pupils in their charge and to the raising of their standard of living.

On the other hand, those teachers who have most bravely put aside traditions of school procedure in teaching and learning, and have set their ambitions on the attainment of new values, have already obtained encouraging results and found cause for rejoicing. The fact that the children have not the intellectual endowment which enables them to deal effectively with abstract ideas does not mean that they have no mental gifts. It has been found that a large proportion are quite capable of thinking and of learning, provided that the subject is related to concrete experience and practical activity. Divorcing knowledge from the realities of life is wasteful in the teaching of any type of child, but is entirely fruitless in dealing with the child whose interests lie in the practical conduct of the affairs of his life.

There is yet another aspect of the problem relating to the education of the Senior School child, which requires immediate attention. Children born in unhappy and sordid circumstances, in conditions of disease, poverty, and crime, may have generally impaired health, weak nervous constitutions, and inferior or unstable mentality. Other children, well cared for at home, are delicate and consequently slow to develop. These types of children form a larger part of the Senior School than of any other school, and may, especially in the poorer city districts, form an alarmingly large proportion. Not only are all such children incapable of prolonged concentration and sustained effort, but they make positive demands on the school to give them every assistance in the amelioration of their life as a necessary condition of their educability.

Apart from the general principles of education and school organization, apart from the details of administration of a Senior School, those who share the responsibility of educating so large a proportion of the nation's children must bear in mind that concrete and practical experience and activity must replace abstract and academic procedure, and that ideals of positive health must activate the life of the school. The curriculum as a whole should be designed with these ends in view; and, the more completely the curriculum is an organized whole of correlated activities instead of an aggregate of disconnected subjects, the more effective will it be in providing a rich and stimulating education in the course of which the children, as individuals, realize themselves and express their personality.

The following pages set forth the claims of nature-study and elementary biology in making important contributions to the general function of the curriculum and the establishment of a life-long interest and enthusiasm in the children themselves. They should also provide assistance and guidance out of the fullness of past experience to the teacher in his difficult task.

Physical and Biological Science in the Curriculum

Whatever subject of study has reference to the expression of the human spirit since the beginning of days is entitled to an honoured place in the curriculum. The humanities, the arts and the sciences represent the great pathways of human achievement, and these must be represented in any liberal and generous education.

In these chapters we are concerned with the special function of science as an element in culture and civilization. To many teachers the word science connotes some form of physics and chemistry, and they advocate its inclusion in the curriculum as a mental discipline as well as a study which yields many useful and practical gains. Physical science and mechanical invention have probably made greater changes in the condition of human existence during the past 150 years than in the preceding twenty centuries. We are rightly proud of the contribution which such scientific and inventive genius has made to human progress. In recent times, however, we are beginning to realize that machinery was made for man and not man for machinery, and that purely physical science may actually be detrimental to human progress, unless biological knowledge keeps pace with it and draws attention to the central aim of racial improvement.

Considering the matter from the purely cultural point of view and assessing the value of biology as a subject of instruction in the Senior School, we have to assert that physical science will put the pupil into intelligent relations with one aspect only of his surroundings, giving him no help in understanding his fellow creatures and himself better and in learning to appreciate the living world of which he is part. Our purpose is to advocate, not an unscientific, but a balanced and biological outlook upon existence—a habit of mind, which, while recognizing the wide intellectual range which physical science has given to man, keeps in view the fact that biological knowledge, the recognition of biological truth, makes its own special contribution to man's control over his environment and to his culture and progress.

From the study of living nature man has derived many gains. In virtue of his knowledge he has learnt to increase the fertility of the sea and the fruitfulness of the earth, he has learnt to control disease, and to promote social health and general welfare. These are practical contributions towards "the relief of man's estate." The cultural gains are in no way inferior—breadth of vision, an approach to truth, fine perceptions and sympathies are good beyond compare. Nevertheless, the old mystery must be emphasized: that if science, like the goddess of fortune, is pursued for any of these gains, she will never be captured nor will her values be realized. Therefore the fundamental concept of nature-study must be disinterested love of nature and desire to understand her ways. If study of nature is thus pursued with singleness of purpose, then, and then only, will she bestow her gifts.

It is easy to awaken and cultivate a love of nature in children. Curious and beautiful things abound and make an appeal to which they readily respond. Children differ enormously in their tastes and interests, but there are certain aspects of nature which few can resist, and these may become regions of early exploration.

The Teacher of Biological Science

The love and enjoyment of the ways of nature and a desire to understand them characterize the early days of any scientist. If, in the course of their education, children are to be taken but a little way along the great road of science, following their leaders, this must be their first experience too. It is equally clear that only a teacher who knows the way by personal experience can be a reliable guide and animate his pupils by his own enthusiasm. This assertion has the appearance of a demand that nature-study should be in the hands of a specialist, a state of things which is still not general in a

Senior School. Although a specialist teacher with scientific training, who is at the same time a field naturalist, is probably the best member of staff to teach the subject, yet it cannot be maintained that such qualifications are essential. Any teacher who delights in field-lore, and to whom the practical preparations which nature-study entails in and out of school are no burden, can inspire and guide his pupils.

Whether a teacher is a scientist or only a disciplined and educated nature-lover, he will find the way to interest the children by bringing them into contact with the same aspects and processes of nature which have made profound impressions on him in the early days of his life as a naturalist. He will thus know how to select the material for study which is likely to appeal to all, however much they may differ in tastes and interest. The great pageant of the season punctuated by outstanding events, the path of the sun across the sky, and the changing shadows, the curious and winsome ways of the animals, the beauty of the flowers, the rain, the pools, the streams, the behaviour of the wind and burning fires, are all topics which readily stimulate inquiry and bring delight.

The Study of Nature in Town and Country

Although intercourse with nature is the rightful heritage of all children, it cannot be denied that conditions allow city children only a meagre portion of their inheritance. It is futile to assume that the study of nature of city children, especially in poorer parts, can be identical in scope or character with that of country children. Quite apart from wealth of material at the disposal of the young naturalists, country children take an entirely different attitude towards the ways of nature. Their home-life, centring, as it does, round work in the fields, which in its turn is governed by the periodicities of the seasons, provides fundamental nature impressions which are only dimly experienced by the city child. The profound race experiences of tilling the soil, sowing, reaping, and harvesting, all in tune with the seasons and always accompanied by hopes and fears, form a definite mental background for the biology lessons, as does, also, the experience of life of the animals dependent on man, with its phases of growth, development, and reproduction.

The outstanding features of biological science in rural schools should be its all-pervading influence, the sense of reality and importance with which it is viewed, the common interest it entails between school and home, and the fact that it may become the basis for a vocational education. The whole life of the country child expresses a relation to the world of nature which is fundamental. Whatever natural science is practised in school, it should in the first place help him to see the significance of the phenomena and processes with which he is already familiar and to rationalize his experience. In the case of the town children, the first need is to extend their experience and to foster their love of nature, which is in danger of being starved out of existence.

While it is fully recognized that the study of nature in rural schools differs from that in city schools in general character, in range, and in significance, it is nevertheless possible to plan a scheme of work suitable for both types of schools, embodying the general aims and values of biology in education, providing experience in scientific procedure and developing a biological outlook upon life.

Such a scheme will receive detailed attention in the following pages, but in order to stress the special character of rural nature-study, over and above the more formal work of science in the curriculum, a general survey of the children's activity in a country school will not be out of place.

SPECIAL OPPORTUNITIES IN THE COUNTRY SCHOOL

In spring time, when the fields are ploughed and the ground in the garden is prepared, the sowing of seed is the main operation at home and in school. The children should learn to identify the seeds of common food plants and should study the relative advantages of sowing seed broadcast, in drills, and setting each seed separately. They should see the operations in the field and discuss the significance of each process. The study of seedlings would naturally follow as they make their appearance above ground. The parts of a seed may be examined in the classroom, and drawings made to show the great variety of seeds and seedlings.

The study of birds would link school work with the pursuits of leisure moments. Learning to identify birds by their appearance and behaviour, and cultivating the habit of patient watching and observing, will do more to prevent wanton destruction than any admonition. As one beloved flower after another makes its appearance, specimens should be brought to school, examined, and described in word and drawing. Life in ponds and streams is always a source of delight, and frequent excursions in and out of school hours will ensure that the children note successive phases of development and peculiarities of structure and habit, which can be discussed and summarized in the classroom. The children should keep nature notebooks in which discoveries are recorded.

A special feature of country life is the appearance of young things among the animals on the farm and in the field. Valuable lessons may be given in the school on the relation of parent to offspring, which ensure a clean and objective introduction to the problems of sex in animal and in plant life.

The work should be organized so that the activities in the garden set forth the relations between the various occupations and the seasonal change in nature. The interdependence of animal and plant life, the relation of plants to soil and air, the water supply, and the bonfire are all facts of interest that may be intelligently explored.

During rambles to the scene of action, the attention of the children should be directed to all typical rural pursuits, and they should be encouraged to find reason and purpose in the work and learn to admire the skill involved.

Excursions should become expeditions of adventure and discovery, during which the names of common trees and flowers are learnt and their habitat determined; animal life should be observed in wood and field. A pond should be visited and compared with a brook and stream.

In some out-house or shed some animals, such as rabbits, mice, or pigeons should be kept, so that the children may become familiar with the facts of growth and development from egg to egg or birth to birth, provided that the difficulty of arranging for the care of the animals during week-ends and holidays can be overcome. Perhaps children could bring their own pets for the week, and take them away for the week-ends and holidays.

Values of Biology

1. GENERAL EDUCATIONAL VALUES

Whether biology is practised in city schools or in the country, it must prove its value and justify its existence in the school time-table. If conducted and practised in the right way, it will develop and discipline the gift of seeing. The power of observation is a hereditary endowment, but it can be vastly improved by proper functioning. If the objects studied are sufficiently beautiful and interesting to the children, the task of description, comparison, and identification certainly cultivate precise vision. The nemesis of unawakened or stifled interests is general boredom and apathy frequently leading to misuse of life's leisure. The children's healthy curiosity in their surroundings being stimulated and educated so that scientific inquiry becomes a habit of thought in the presence of the strange and unknown, interests are certainly widened, and food for thought and work for hand are found that mean recreation during holidays. Intercourse with nature cultivates the sense of beauty and touches the harp-strings of imagination, so that the enjoyment of things becomes a definite asset.

2. SPECIAL VALUES

In many schools it has been found that nature-study and biological science have vastly improved gardening and poultry-keeping and have rationalized the principles of hygiene. Although this achievement would hardly entail a disinterested approach to nature, it provides a practical illustration of the way in which man, through study, is gaining control over his environment and himself, and leads to an appreciation of the fact that biology has made enormous contributions to "the relief of man's estate."

But it is on account of its culture values that an honoured place in the curriculum is claimed for biological science. Some form of living nature-study in a living curriculum ensures enrichment of the mind and vision which are necessary for the proper conduct of life. The old fundamental impressions of the pageant of the seasons, of the immensities of the starry sky, the mountains, and the sea, have influenced human life since immemorial times, doubtless giving to man his first ideas of orderly uniformities. Further, biology, if rightly pursued, will ensure, even for young students, a vivid realization of the primary facts of life—birth and death, growth and development, the inter-relationship which bind parent and offspring and all living things into one intricate web of life. Such a mental equipment is no mean contribution to the education that makes for culture and control.

Aim of Biology in the Senior School

Being clearly conscious of the significance of biology in the curriculum of the school and of its values, the teacher will aim at securing a fair measure of such values. He will ensure that the work is scientific in character, providing for the pupils a direct approach to the world of nature around them. He will see to it that the work is objective and practical, books being used only to stimulate a wider interest and knowledge. The children should learn to see and to understand *by experience* the appearance and manner of living plants and animals, and should become more and more disciplined in observation, inquiry, and description. The result should be the acquisition of a foundation of concrete facts of experience, and finally the development of biological concepts in the light of which the pupils see plan, order, and meaning in the world around them, and understand themselves better in relation to it all.

General Method of Learning and Teaching

In days gone by it was the practice of students in training to prepare for their lessons elaborate notes in which the subject-matter of the lesson was clearly marked off from any indication as to the method of teaching it to the class. Indeed, the very staff of the training colleges comprised "subject lecturers," who were specialists teaching the various subjects of the curriculum, and "method lecturers," who trained the students in methods of instruction. Teaching has since become rationalized through child study and psychology, and we realize that, although we can lecture on any subject to students and set forth a method of teaching adults, no lecturer on method can effectively teach the particular method of any subject unless he is a specialist in that subject. Subject-matter and method cannot be divorced in theory or practice as far as the function of teaching is concerned. We therefore propose to give a descriptive account of a three years' course of biology in a Senior course, paying attention both to content of the scheme of work and to general method of procedure, as opportunity requires.

As a matter of general principle, some aspects of classroom procedure, routine, and management may be emphasized at the outset, since they characterize the work throughout the course—

1. The formal lesson of observation directed by questions, description, and recording of facts observed in notes and drawings has its place, but that it should be the only way of studying implies a mistaken conception of learning. Systematic description and logical arrangement is a feature of science technique and has training value for young students. But to make "training in scientific method" an end in itself, and not only an effective means to an end, means dead and stereotyped procedure. Spontaneity and enjoyment, the dynamic forces of study, require constant regard for individual reaction. The systematic and orderly arrangements of notes and drawings must be the outcome of personal taste, interest, criticism, and discussion rather than of adopting a given plan. The work of the children creates its own technique, and both develop with experience and living interest.

2. Descriptive biology lessons, especially if accompanied by drawing, painting, and constructional work, may form a considerable part of the biology of the younger children, but when innate curiosity merges into the more disciplined spirit of inquiry, when problems present themselves, and the strange behaviour of animals and

plants demands an explanation, two types of work, both important aspects of "scientific method," should receive attention. On the one hand, continued observation on growth and changes, and, on the other hand, experimentation, become the order of the day.

3. We may at this stage ask ourselves what is the relation between the descriptive lesson on isolated specimens and the study of changes in growth and development? By the examination of a variety of plants and animal types we extend our acquaintance with the living things of our environment—our thought-world becomes more and more richly furnished. But, valuable as this may be, it tends to develop a static concept of the world. Things appear as fixed and given, and yet life is all flow and change. The study of change with its continuity leads to a realization of the nature of the living world. Moreover, the constant demand that the changing thing makes on the attention of the observer means constant mental functioning in reaction and adjustment on his part and keeps him alert and interested.

4. The more we teachers indulge in the formal class lesson, the easier class management and routine is found to be. The method makes its appeal to the destitute teacher. One difficulty will, however, always be experienced, especially in city schools. It may be comparatively easy to buy thirty or more wallflower florets, or an equal number of beans or peas. House-flies are often not scarce, nor earwigs when the dahlias flower in back gardens. But when the aquarium season is at its height, and caddis worms, water-beetles, and dragon-fly larvæ engage our attention, the provision of adequate specimens for class instruction becomes a serious problem. Quite apart from the practical difficulty of obtaining specimens, it is at no time desirable that large numbers of animals or plants should suffer in the name of elementary biology. Add to this the fact that the pupils themselves will bring curious and beautiful things to school, if the love and appreciation of these has been fostered by the teacher. These considerations point to the fact that group or individual work is often expedient and always profitable. The habit of quiet, serious work in examination, writing, and drawing is easily acquired by pupils of Senior School age. If the class is treated as a natural history society, the reading of papers, the exhibition of records, and the common care of animals and plants kept in the class-room will provide the contributions to the common life of the class community.

5. The Senior School has a unique opportunity and privilege in its way of conducting a biology course. It may free itself from all the traditions and conventions of teaching which fetter both nature-study and biology in so many other types of schools. Instead of wasting energy in deploring the lack of intellectual gifts in the children and their short period of education, instead of imitating the tasks of established and more favourably placed schools, and failing, the Senior teacher may shoulder a new and hopeful task.

6. If the scheme of work outlined in the following pages is critically examined, certain outstanding characteristics will become plain. The "lessons" will not conform to the periods for biology in the school time-table, though these periods will be used for the study. The scheme contains lesson-units which may be continued from week to week, and their structure does not become evident till their completion. Such a lesson-unit may comprise, for individual children, for groups, or for the whole class, periods of practical study of animal and plant life, writing, drawing and painting, making arrangements for the housing of insects under observation, attending to the aquarium and plants grown in the classroom, preparing specimens for a museum or making apparatus. An integral part of the work should consist of reading to the class by a teacher and reading by individual children when need and opportunity occur. Needless to say, rambles by the class or individual out-door work by the children, as well as gardening, should form a factor in any biology course, and should be a prominent feature of the work in a rural school.

Let the teacher of a Senior School who has the infectious love of nature and of children, appreciation for intellectual truth and scientific procedure, ability and imagination to organize, take courage, set his face to the wind, and further the cause of the nation's children.

SCHEME OF WORK IN BIOLOGY

General Outline

In order that aims in teaching may be realized, that the scheme of work may represent a coherent whole in which each part has its appropriate place and which is progressive in technique and in mode and habit of thought, it is necessary to plan a general argument, and thus give it a dramatic form. The rhythm of the seasons, punctuating the course of nature, including mankind, should be a fundamental impression. Each season brings with it certain characteristic events, some easy to apprehend and some subtle and far-reaching in meaning, often affecting human life. The former may come to the notice of the younger children, while the latter may provide subjects for reasoning and reflection to the maturer minds. Thus, as the seasons come and go, they will bring ever new scenes to the interested spectators in the Senior Schools and thereafter.

The work is assumed to extend over three years and is arranged according to six-monthly periods.

I. 1st Year: October—April

Autumn is the season of fruitfulness. The fruit and how it has developed from the flower. The seed is the beginning of a new life, which in plants and in many animals starts an independent existence. Dispersal of fruits and seeds. Consideration of the value of dispersal and the advantage of direction and control in making the process effective: thus some seeds drop from the broken capsule by chance; many fruits and seeds have structures that facilitate dispersal; gossamer spiders start their sailing by instinct at a suitable time; migration of birds is initiated and the course controlled by complex instinctive reactions; emigration of man is induced and directed by knowledge and reason.

A period of rest and apparently uneventful existence follows, illustrated by dormant seeds, bulbs, buds. Ancient nature myths and legends express the drama of the seasons. Christmas time and its significance in ancient days.

In spring seeds, buds, bulbs, bulbils, shoots, etc., all young plants and innumerable young animals learn how to live.

II. 1st Year: April—October

In early summer the abundance of life is striking and young things people the world. Variety and manifoldness is as impressive as number; the teeming inhabitants of the pond, the flowers in fields and woods, and the life of the vast company of insects, all testify to the truth of these impressions. Bees and ants set forth a way of organizing great numbers of individuals into a community.

III. 2nd Year: October—April

The consideration of the enormous increase in the number of living things raises the problems of over-population. The meaning of the struggle for existence for self and for kith and kin; the general endeavour after well-being and work for a living become appropriate topics for discussion. In Autumn the wider meaning of the word harvest and of food stores as results of summer activity become subjects of interest.

Winter sleep is typical of the next phase in the seasonal rhythm, and indicates, on the one hand, a reaction to excessive activity, and, on the other, a means of evading the struggle for existence.

Spring is, as always, the season of young things, but is also the season of parents. Attention may now be given to the relation of parents to their offspring and their devotion and care. Young creatures play. The meaning of play. How far plants can care for their young.

IV. 2nd Year: April—October

In summer young things are active and grow. They may be seen developing and growing up, often changing greatly in the process. It may be seen how they feed, breathe, protect themselves and make a living.

V. 3rd Year: October—April

Autumn is also the season of decline and death. Beautiful autumn tints of leaves are associated with their fall and decay. Bacteria and moulds are agents in the process of decay, by which the bodies of living things return to dust. The soil thus receives the dead and supplies necessities to the living. Reference to bacteria leads naturally to a consideration of "germs" as agents of disease and to the work of Pasteur and Lister.

The infinite variety in living things is beyond conception, impressive in spring time, but obvious in all the seasons of the year. That they are fundamentally alike is an equally striking fact, for the business of all is to feed, breathe, make the best of circumstances, and reproduce their kind. Even as regards their structure, the cell is the physiological unit of each and all, as well as the starting point of their individual existence.

VI. 3rd Year: April—October

The cells of which the bodies of animals and plants are composed by their multiplication and differentiation form tissues and organs in close relation to special functions. The bodies of animals and plants may be relatively simple as those of amoeba, pleurococeus, hydra, spirogyra, earthworm, moss, or relatively complex as those of snail, fern, fish, pine, rabbit, buttercup. Animals and plants are found to form ordered series of increasing complexity of structure and organization. The knowledge of these facts has made a classification of animals and plants possible and has contributed enormously to the realization that there is order in the living world.

Every living thing starts its life as a single cell and grows according to its kind. That in one case the single cell should grow into a rose, another into a squirrel, and yet another remain an amoeba is one of the wonders of the world. It is all a matter of parents, without which no living things come into the world, as far as we know. Through them the characteristic marks of the species and other qualities are transmitted to the offspring. This transmission is called inheritance. How far the individual factors of the inheritance are realized and expressed in the individual life depends on opportunity. Thus both nature (inheritance) and nurture (environment) determine the individual life.

SYLLABUS AND GUIDE TO METHOD OF TEACHING

I. 1st Year: October—April

Autumn Flowers

Study certain typical autumn flowers which may easily be obtained in considerable numbers, so that general class-work, conducted by the teacher, is possible. Nasturtium, scarlet runner beans, snapdragon, and sunflower are recommended.

The children should examine the parts of the flowers and learn the technical term for each. They should draw the whole flower as well as the various parts. The drawings must be large and in outline only. So-called shading must not be allowed, but painting in flat washes of water-colour, carefully chosen, is most desirable, ensuring colour discrimination and enhancing interest and enjoyment. The description of the flowers, although systematic in form and designed to teach the formation of fruit and seed in a plant, must not be too specialized, and should contain reference to other parts of the plant and to the relation of the latter to its environment, thus making the study biological in character. The following notes represent the outlines of a lesson on an autumn flower to indicate the method of procedure recommended.

NASTURTIUMS

The home of nasturtiums is South America, where they grow wild in the rocky regions of the Andes. Seeds were brought to England by monks as long ago as 1640. The seeds were sown and of the new plants the seeds were kept and sown again. This was done year after year. Consider that each plant came from one seed and may easily produce ten seeds. It is easy to understand how the handful of seeds of 300 years ago has made it possible for every garden to have nasturtiums. In examining the flower the colour of the petals is probably noted first, and this leads to observations on their constant number and their form. Reference may be made to insect visitors which see the brightly-coloured flowers or are aware of their scent. They visit the flowers, settling on the big petals which make a platform. They may crawl inwards and find shelter. They may also find food and come over and over again. Nectar and pollen are the food of many insects and of their young; in searching for nectar the insects tend to follow the dark lines on the inner surface of two of the petals. In tracing their course, the outer leaves (sepals) of the flower receive attention and are described. The spur, often containing nectar, is specially interesting. The way to it is blocked by the fringe of bristles of the large petals, and only strong insects such as bees can get to the spur. In their efforts to reach the spur they become dusted with pollen. They may often be seen brushing themselves with their legs and keeping the pollen in the hairy pockets of their hind legs, flying away with it. Discussion on the subject of pollen leads to the examination and description of stamens which stand up right in the way to the nectar.

In older flowers it will be found that the stamens are withered, but the way is blocked by another structure. Examination of this implies the study of the pistil with its suggestion for seed formation. Bees visiting this kind of flower are likely to rub against the stigma in their way, and so lose some pollen from their coats. This is a fortunate thing for the nasturtium plant. It is difficult to understand first what happens, but the seeds in the pistil only "set" and grow if some pollen which the bee or the wind has brought from another nasturtium flower gets caught on the stigma. When the flower dies the ovary becomes more and more sharply divided into three parts. Each of these is a seed case, or fruitlet, containing one seed. When the fruits are ripe they are brown and their outside covering is light and spongy, as it is partly made of cork. This the children can see, and can prove that the fruits falling into a puddle of water float and would be carried away in rushing rainwater. In their own home the seeds are doubtless washed from rock to rock until they get caught in some crevice, where they may take root.

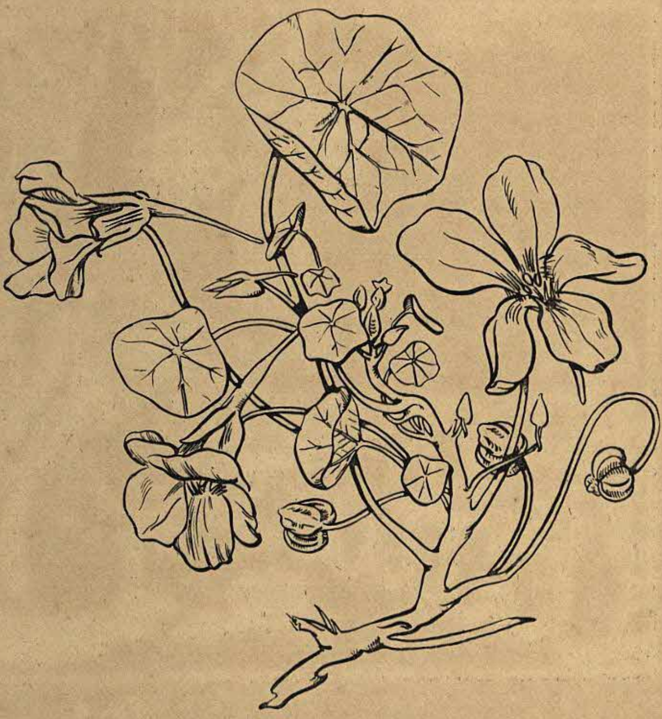


FIG. 1

The Nasturtium

The leaves of the nasturtium plant may finally be examined: few plants have leaves of this kind, spreading the whole blade to the light. This may be seen in any garden where nasturtiums grow, and their sensitiveness to light may be demonstrated by experiment—

A piece of looking-glass may be laid on the ground near nasturtium leaves in such a way that the sunlight is brightly reflected from it. The leaves will turn down towards it, catching the light from the mirror.

Fruits and Seeds

A great variety of fruits, obtained from the neighbourhood of the schools and—in the case of urban schools—from shops, should be examined. First the class method may be adopted, so that the pupils may have a plan of action made intelligible by reference to their flower studies. The fruit is the ripened ovary in the great majority of cases and consists, therefore, of the ovary wall, now called fruit-wall (pericarp), and the seeds. This is true in the great majority of cases, but at a later period the conception has to be modified when rose-hips and haws are examined and additional parts of the flower are found to have taken part in fruit formation. A perfectly simple classification of fruits may be the result of comparing and contrasting the fruit types studies.

FIG. 2

Autumn Fruits

From the biological point of view, however, the importance of the fruit lies in the fact that it is the last expression of the activity of the plant and the starting of a new generation. The seed is the essential part, but the fruit wall is protective during the period of ripening and contributes much to effective dispersal.

Fruit and Seed Dispersal

That the fruits become naturally detached from the parent plant is a fact of general experience. To trace their subsequent destiny is a function of the biology class. From the study of a large and varied number of individual types of fruits, the pupils will deduce the methods of seed dispersal. At this stage records in the form of drawing and painting should give scope to individual work and taste. Charts may be made to give a graphic survey of fruit and seed dispersal. The sheet of paper may be divided into a number of columns allocated to different methods of dispersal. Each column should have a suitable heading in good script writing and below this a picture of a scene would give reality to the record. Thus pictures of wind-swept landscapes, windmills, flying birds, sunlit landscapes, suggesting dry, hot weather, blackbirds and thrushes pecking and eating fruit, and hairy animals in fields would all be relevant subjects.

Significance of Dispersal

Teachers are strongly recommended to encourage free expression of opinion and discussion at suitable moments in their classes. Seed dispersal has far-reaching meaning which is only realized when actual facts are faced. Thus seeds contained in many kinds of fruits should be counted. The number of seeds produced by all the fruits of one plant may be roughly ascertained and the number of seedlings estimated. Let the children write compositions based on experience of the journey of a seed and let them realize that their dispersal chart only represents a generalized and ideal plan. An important biological principle like that of dispersal is not confined to the ways of plants. Animal life shows the same tendency. The children may consider how the young of the common creatures they know leave their homes from necessity and the dangers that beset them.

An important autumn study may engage the interest of the class. While seeds are quite unconscious of their journey and have no choice or control in their manner of travelling, inquiry into many forms of animal life shows all grades of choice and efficiency in control. Formal lesson or individual studies and reading by the children would make this theme of the autumn season stand out in bold relief. Gossamer spiders and their sailing in the wind on a raft of silk would form a link with wind-blown seeds and would awaken an interest in the life of spiders. Both house-spiders and garden (cross) spiders may be found in numbers, and the latter frequently spin silken cocoons and lay eggs in captivity. Lessons on bird migration may be brought in close relation with this topic; for, although the primary stimulus for this migration is not the emigration of the young from overcrowded homes, it is nevertheless a life-saving device when conditions present

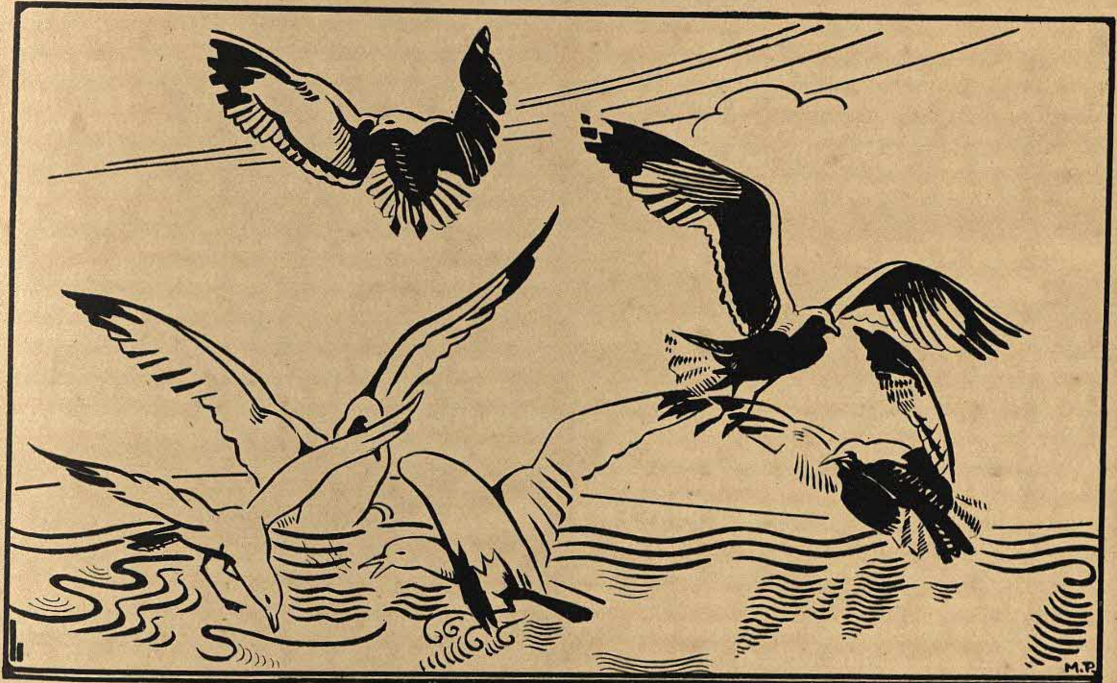


FIG. 3
Flight of Birds

insurmountable difficulties. Country children have innumerable opportunities for watching birds, noting which kinds migrate, which stay with us, what preparations are made for migration, when it occurs, and how the mental life of the bird, with its instincts and ability to learn by experience, makes their migration a vastly more complex and certain thing than the dispersal of seeds.

Mankind makes no exception to the trend of nature. Reading accounts of the nomadic habits of Bedouin and Kirghiz tribes, of great migrations of nations, of the practice of emigration of families and individuals, will give the autumn scene of dispersing seeds wider meaning.

Bulbs and Trees in Autumn and Winter

A resting period in plant life. Bulbs and winter-buds of trees.

Even while there is feverish activity displayed in fruit ripening and seed-scattering, there are signs of decline and death among plants. Just as the young plant in the seed does not generally start growth immediately, so many other parts of plants cease growth, but continue their life in a dormant state. The children will realize this fact, if their experience centres round some forms of plant life that are of interest and that exhibit the phenomenon of rest in a striking manner. Bulbs intended for the classroom or the school garden enter our life in the autumn and will form suitable material for study. They may be examined and described. They should be measured and drawn accurately to size or to scale. Some may be weighed. Their later condition may then be compared with the present state and the consciousness of continuity and change will be established in the minds of the children.

The trees in their autumn glory engage the attention of any thinking mind and therefore that of the children. Although the primary cause of autumn colour and leaf-fall is not as yet within their intellectual compass, the fact of the bright colours of dying leaves and of their falling cannot pass unnoticed. It is, on the one hand, a means of stimulating and training aesthetic emotion and, on the other hand, it has intellectual values in colour discrimination and in the identification of common trees in the environment of the school.

To press and neatly mount beautiful leaves, to name them, to write short notes below them with regard to some important features of shape, venation, etc., and make a collection of such sheets would provide practice in science technique.

The falling leaves draw attention to the condition of the twigs with their leaf scars and pores (lenticels) which now become clogged and closed, preventing the escape of moisture while the tree is dormant and therefore the roots inactive. They also prevent the passage of gas in breathing, and, as the tree thus "holds its breath," retaining its carbon dioxide, which is a narcotic, its sleep is all the more profound. It is, however, the buds that concern our pupils most. Lessons in observation and comparison, drawing to scale and accurate colouring, lead to the identification of trees and to much individual work in school and out of school on the part of the pupils.

Christmas

Deeply ingrained in the life of the race is Christmas time. Interwoven with present-day customs and festivities are remnants of the ancient past with its nature-worship. On the sixth day or on the sixth night of the sixth moon after the winter solstice (December 21st) the Druid priests went forth to cut the mistletoe from the oak. The significance of this act, the symbolism of mistletoe, holly, fir, ivy, and other evergreens, the story of Baldur, a typical nature-myth, the legends surrounding the event of Christmas—all have their place in a broad, generous biology course, in which all such matters are regarded as reactions of the mind and spirit of man to the power and mysteries of nature.

Charts of Growth

Spring—the time of growing bulbs and seeds, unfolding buds and opening eggs.

The first striking event in the biology course is the fact that the bulbs for the classroom and

FIG. 4

Christmas Evergreens

home are showing signs of wakefulness and growth. They must be brought out of their dark nesting places. Apart from verbal reports of growth and change and of other discoveries which are generally stimulating, the biology course requires records free from all personal desire and other subjective elements. "My bulb has grown an awful lot" is a statement that cannot be accepted by our austere science with its love of objective truth.

The most accurate record of growth, free from moods and desires, requires measurement and drawing to scale. Whether we are observing shoots of bulbs or seedlings, measuring and drawing at regular intervals of time and placing the drawings side by side in graph form is the kind of record accepted by science.

Divide a large sheet of paper or cardboard by means of vertical lines into a number of equal spaces, representing intervals of time. The title Seed Chart, Tulip Chart, etc., can be printed along the top. Each column is headed by the proper date. A horizontal line across the columns representing the ground level is drawn near the bottom of the sheet, if bulbs and seedlings are studied without regard to the growth of their roots. Seedlings in glass jars whose roots are measured as well as the shoot require a ground line across the middle of the sheet.

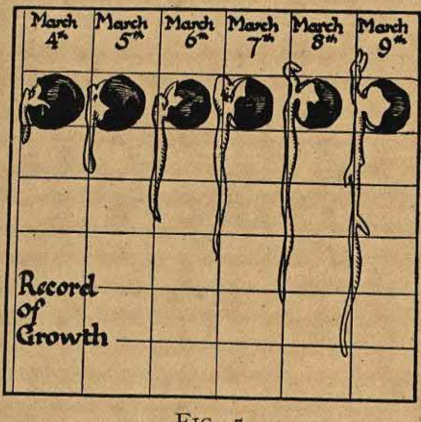


FIG. 5

Chart of Seed Growth

In the case of pupils who are equal to the task of measuring shoots in inches or centimetres and their fractions, the chart may be provided with a scale along the side. The actual measuring of the shoot is confined to the main axis, and is best achieved by means of a strip of paper or piece of tape held upright against the shoot from the ground level to the apex. This distance is then marked off in the appropriate column upward from the ground level and the shoot is drawn within this distance (see Fig. 5). Obviously the more advanced pupils can use the principle of this method for the plotting of graphs with or without drawings of the actual specimens.

Study of Seeds and Seedlings

The children should learn to recognize many kinds of seeds. They may make a collection of interesting and curious seeds. A box with partitions may be made for the different seeds in the collection and the name of the seeds, in good printing, fixed to each partition. Several kinds of large seeds should be planted in pots, boxes or garden plots. The number of each kind of seed might be counted and subsequently the number of seedlings produced. The stages of germination of any given kind of seed can best be observed if the seeds are planted in straight-sided glass jars, lamp chimneys or large test-tubes. The jar is lined with blotting paper. Seeds are placed about 1 in. from the top edge between the blotting paper and the glass, and the former is held in place, if necessary, by a scroll of blotting paper or a plug of loosely packed moss. In the bottom of the jar there must always be a little water, and the lamp chimney must stand in a tumbler of water. By means of such apparatus the seedlings can be observed throughout their period of growth, without being handled or otherwise disturbed, and the children who have different kinds of seeds under observation are able to compare the seedlings and note essential differences.

The seedlings are learning how to live, and if the conditions of growth are varied the children may note how seedlings react to conditions and which conditions seem to be the more favourable. This can best be done by germinating seeds under different conditions of light, humidity, and temperature. The experiments should be made with different kinds of seeds, and the proportion of seeds germinating should be estimated in each case. The following is an attractive and instructive experiment. Take a small flower-pot with a hole at the bottom. Soak it in water. Sprinkle small seed, cress or mustard, over the inside of the wet pot. Place the pot upside down in a saucer of water. When the seeds have germinated, note the direction of root and shoot, also the root hairs. Place the pot upright, cover with a piece of glass, and note the change in the seedlings.

The Young of Plants

Seedlings are the young of plants. They come from eggs as birds, insects, and many other animals come from eggs. Others are born, such as kittens, puppies, lambs, and human babies. Although plants are not born, many come into the world as more or less complete living young all the same. The bulbs are an instance of this occurrence. Potato cuttings may be grown by the class and the fact that they can lead an independent existence will be appreciated by experiment.

The Young of Animals

A journal of "birthdays" might be kept by some member of the class in which important events in the life of pets and domestic animals are registered with brief notes as to the number of young and the conditions in which they are born. Such a register would be specially valuable in a country school. Sooner or later frogs and newts in the pond resume their spring activities, and the biology class experience the annual thrill of possessing a mass of frog-spawn in the classroom for care and observation. They experience the hopes and fears that are always associated with entrance of young things into the world. Let them estimate the number of eggs in a mass of spawn and subsequently the number of tadpoles—there is nothing like measuring and counting for facing facts and preventing too facile an optimism in the presence of nature. A record of computations

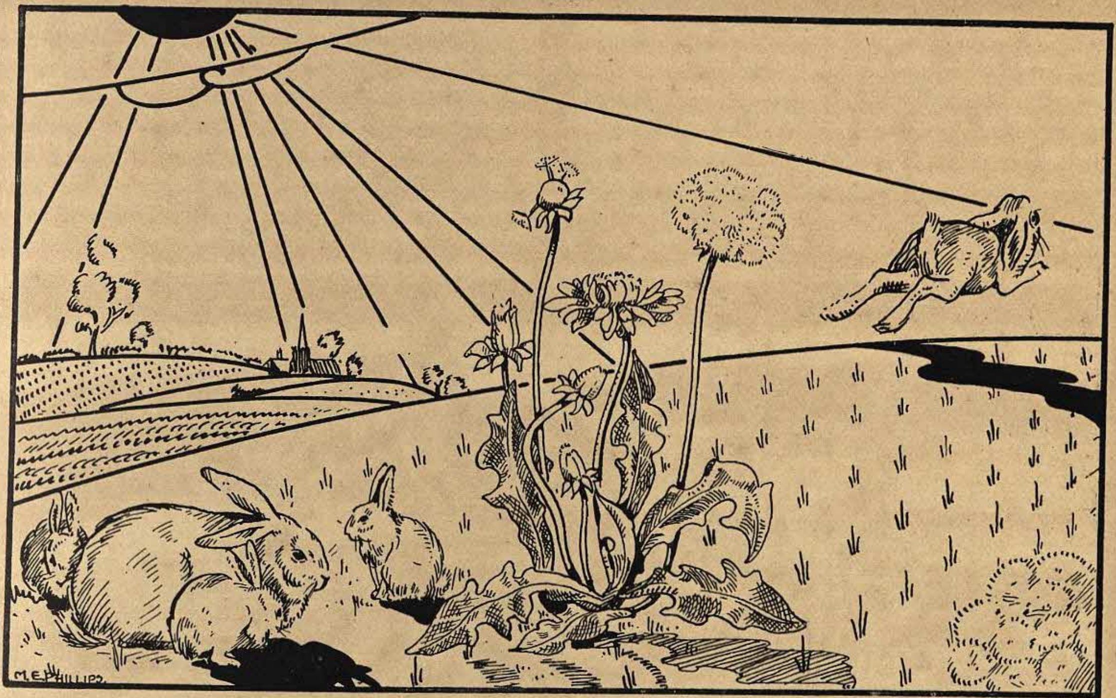


FIG. 6
Rabbits and Young

will demonstrate the seeming wastefulness of nature.

II. 1st Year: April to October

The keynote of the work in biology during the summer period must be the abundance and variety of living things. For sheer numbers the tadpoles can hardly be beaten as far as our experience of animal life in this country is concerned, unless we take into consideration the number of individuals which form the company of some forms of insect life and of starlings. Among plants the carpets of primroses, the golden floods of buttercups, the seas of bluebells testify to the same impression.

The Pond and the Aquarium

The pond is almost a complete biological formation, consisting as it does of animal and plant life in a definite and well-defined physical environment, showing great variety in mode of adjustment to this environment in their development and habits and demonstrating in the clearest possible way the close interdependence of animal and plant life—the web of life.

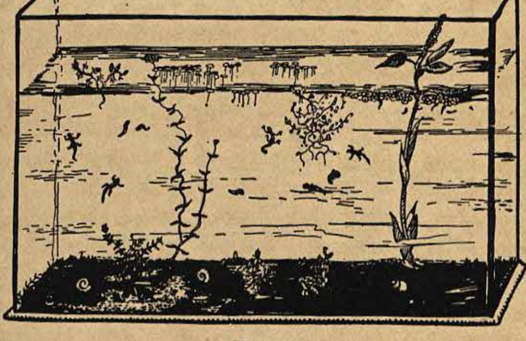


FIG. 7
An Aquarium

An aquarium may become a valuable model of such a formation and, being in the classroom, it affords laboratory conditions for observation.

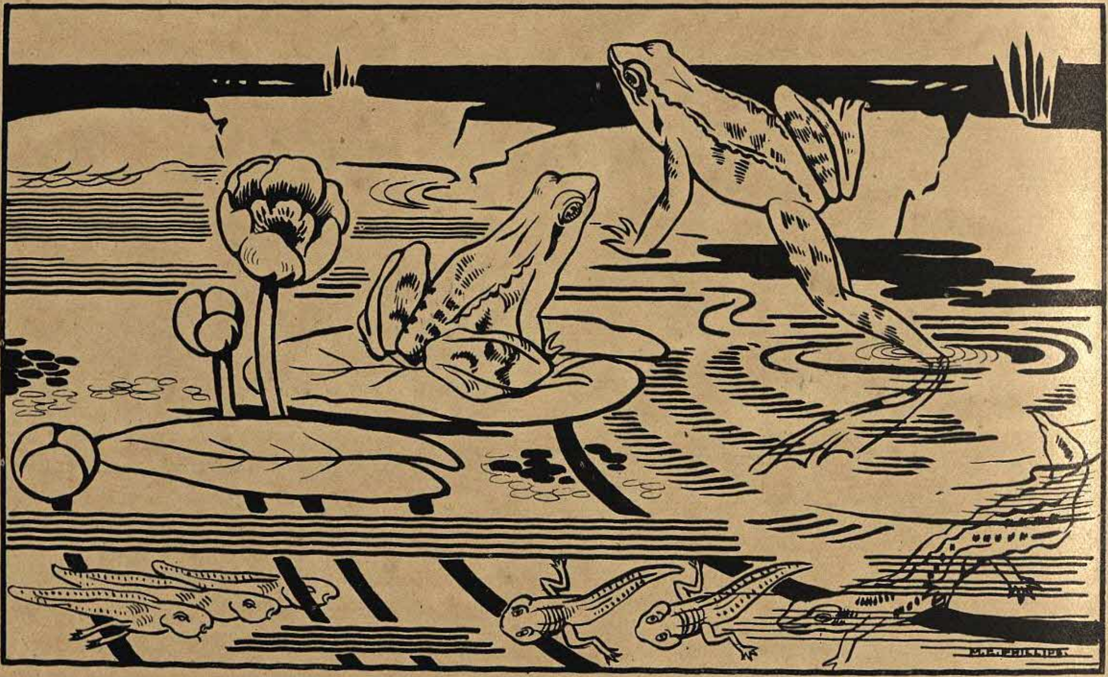


FIG. 8
Pond Life

It may consist of any convenient vessel which does not affect the conditions of the water. Its most important need is adequate supply of air. The water must be perfectly fresh, without being frequently changed. Changing the water means unnecessary and undesirable disturbance. Free swimming animals such as sticklebacks require plenty of space. For most animals a shallow tank is best, because it presents a comparatively large surface of water to the air, where rapidly-growing and developing creatures are concerned. On the other hand, some of the beautiful trails of water-weed look and flourish best in a fairly deep tank. A compromise must be effected, and, as the weeds help to keep the water fresh, they need not be grudged the extra depth of water. At the bottom of the tank place a layer of garden soil and over that a deep layer of well-washed sand. Fix some trails of water-weed to a small stone by means of bast and bury the latter deep down into the garden soil. Place a few large and well-shaped stones for use and ornament among the weeds. Lay a sheet of stiff paper over the contents of the tank. Take hold of the paper with one hand and with the other direct a stream of water from the jug or india-rubber tubing connected with a tap upon the paper. Gradually raise one side of the paper, keeping the stream of water upon its surface. Finally the paper can be taken out and the water should be perfectly clear. Raise the water weeds so that they are buoyed by the water. The work of the pupils should consist of (*a*) the care of the aquarium and its inhabitants; (*b*) observations and records of change of the animals; (*c*) studying their life-history with or without the use of books; (*d*) observations on the inter-dependence of living creatures, e.g. carbon assimilation of water plants studied experimentally and its significance in the respiration of animals; the dependence of many animals on plants for food and the carnivorous habits of others.

The most suitable animals for observation are: frog, newt, stickleback, caddis, dragonfly, water-beetle, and snails. They cannot, very naturally, all be kept together, if all are to be kept alive and in comfort, but care must be taken that they are all fed liberally and regularly.

Summer Flowers

The examination and description of flowers, carried out with increasing accuracy of detail, should lead to a simple grouping of plants into families and natural orders based on similarity in the essential reproduction organs. Interesting instances of devices ensuring cross-pollination should be stressed.

Insects' Life

The study of the life history of a moth or a butterfly lends itself to valuable individual work. Eggs or caterpillars of the Cabbage White butterfly may be found in May and August or September, and also of the Magpie moth, which live on gooseberry and currant bushes. Both are easily provided with food and easy to rear. The children can without difficulty make their own breeding cages in the following way. The small sides of a cigar or other similar box become the top and bottom of the cage. Remove the lid. The two long sides are broken away and cut into strips with a penknife. Strips are nailed to the free corners of each of the small sides in such a way that they connect the top and bottom of the cage. Mosquito netting is fixed over these two sides of the box. A hinge of cloth or webbing is made for the door and fixed to the top of the box. At the bottom a bent pin will make a latch, so that the door can be kept shut. Inside the box should be a little jar of sand and water in which suitable parts of food plants are kept fresh.

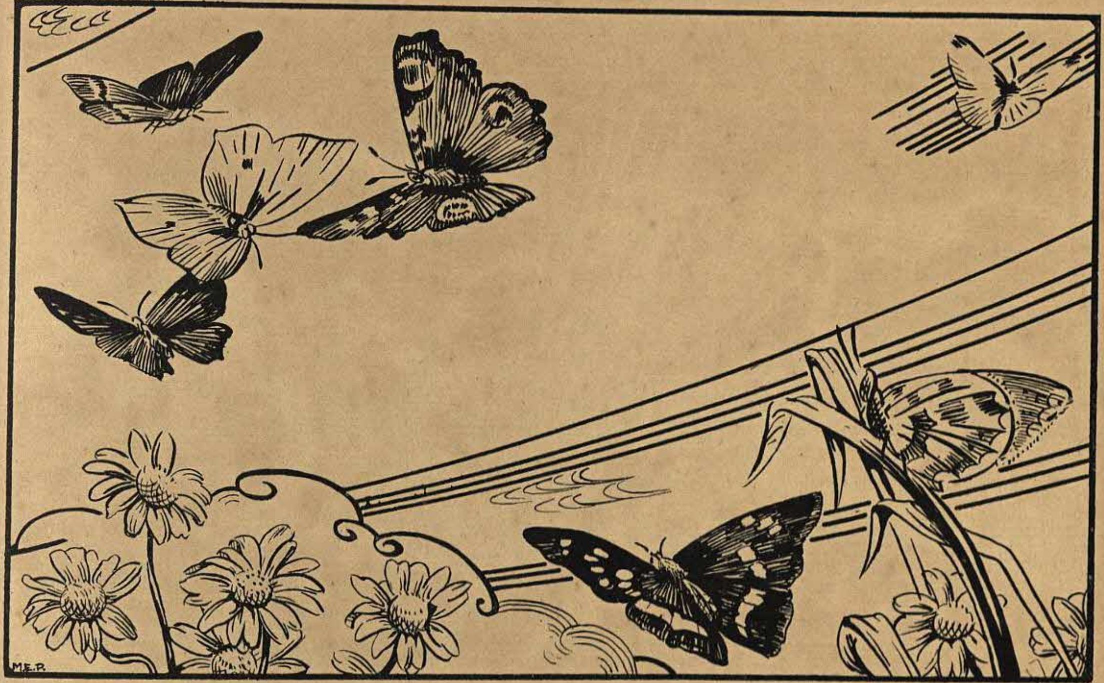


FIG. 9

Butterflies

An interesting experiment may be made with caterpillars of the Cabbage White butterfly, showing the effect of special changes in their environment. They may be kept in cardboard boxes out of the lid of which a piece has been cut. The opening is covered with mosquito netting, admitting air and some light. The caterpillars must be well fed. As they become nearly full-grown they should be transferred to boxes lined with differently-coloured paper—red, green, blue, yellow, gold, black, etc. The effect this colouring has on the colour of the chrysalids should be investigated.

Bees and ants and their social organization form an interesting study, especially for country children. Observations on the life and habits of ants are becoming more possible in classrooms since various designs of formicaria have been worked out and tested. Space does not permit a description of such apparatus here, but information regarding them may be obtained from the list of reference books submitted at the end of this chapter.

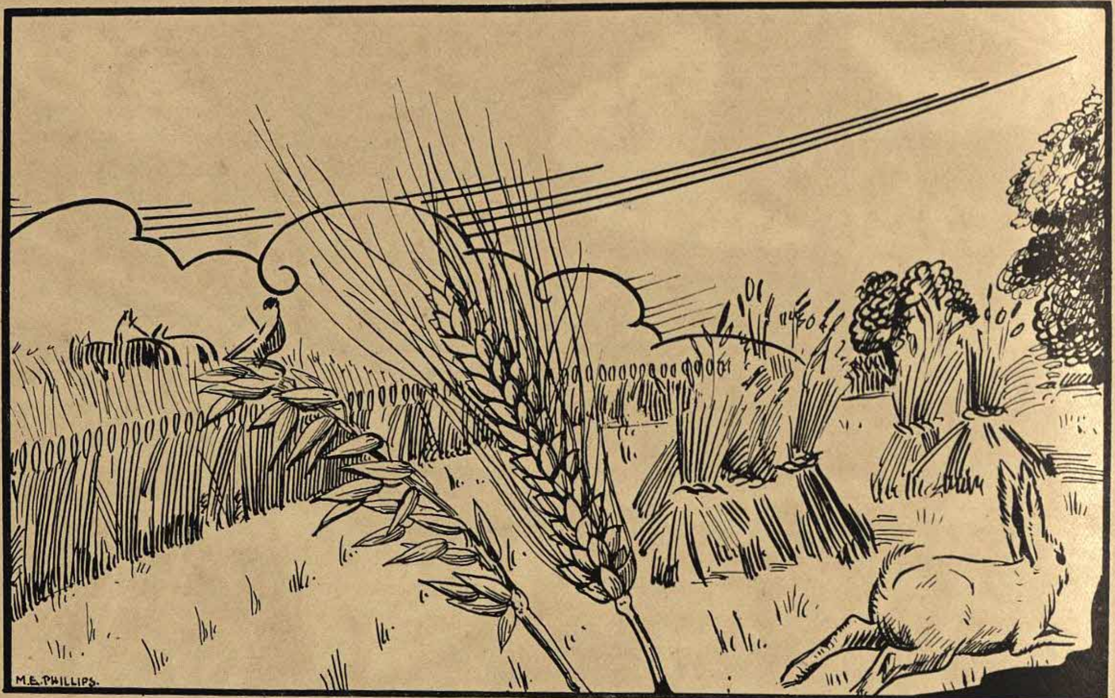

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FIG. 10

Cornfield

III. 2nd Year: October—April

Harvest Time

From the point of view of mankind, the word harvest implies the gathering in of corn and other crops, on which the food supply depends. The children should be familiar with such crops and examine ears of different cereals in detail. In the case of country children the economic value and market prices of certain staple crops should be discussed.

Harvest time has a wider biological meaning which the children should realize. All the ripening of fruits and seeds means harvest to the creatures of the wild. The children should appreciate the truth of the statement that directly or indirectly all animals depend on plants for food.

In order that the biology course in a Senior School, free from the methods of academic procedure, may be closely linked with the realities of human life, teachers are advised to discuss with their class such matters as the difficulty of "making a living" for all concerned. The "living" may mean the obtaining of food, but it also means the obtaining of food for offspring, and it means effort for more than mere necessities of nutrition and a "squabble round the platter";

it means endeavour after well-being. Let the children find concrete examples of these truths among plants, animals, and people of their acquaintance.

Food-Stores

The subject of food materials necessary for animals and plants can be studied experimentally in a rough and ready way by children with little logical ability and skill and in schools with little facility for practical work. The following notes indicate the line of thought and procedure.

Animals and plants need food. Seedlings use up the food in the seed-leaves; shoots of potatoes use up the old tuber. The food supply of plants is made by them and stored up for future use. Our food supply and that of the animals is not made by us, it is found elsewhere and must be specially prepared. The food of animals and plants is mainly composed of water, starch, sugar, protein, and minerals.

Examine many things which we and other animals eat for food. You will find parts of plants easiest to study. Find out what kind of food substances they chiefly contain, proceeding as follows—

1. Look for fruits, vegetables, meat, etc. Weigh a piece of each. It is not difficult to make a balance with matchboxes for pans and seeds for weights. Dry each piece in a warm place and weigh again. The loss of weight shows that it contained water which has escaped.

2. Scrape a little potato, crush wheat or rice, and use a little bread. Put a drop of iodine on each of these things. A blackish-blue colour will appear, which is a sign that *starch* is present.

3. Take a little white of egg and roast it on a tin plate, till it burns. Notice the smell of burnt hair or feathers. This is a sure sign that *protein* is present. Put some flour in a little muslin bag. Knead it and squeeze it in water. A sticky substance remains in the bag. This is gluten. Heat and burn this. You will find that flour, and therefore bread, contains protein as well as starch.

If conditions of class and equipment permit a more accurate test for protein may be applied. To a small quantity of the solid material in a porcelain dish add a drop of concentrated nitric acid and heat. A yellow colour, turning orange when ammonia is added, indicates that protein is present.

4. You can find sugar by the sweet taste in many juicy fruits, nuts, and vegetables, but the following sugar test is obviously more precise—

The material should first be tested for grape sugar, and if there is no reaction the test for cane sugar may be applied.

Grape Sugar. Make an extract of the material to be tested, boiling it gently in a little water. Pour off the extract. To about ½ in. of the extract in a test-tube, add a slight excess of Fehling's solution and boil.

An orange precipitate indicates that grape sugar is present; a green coloration in the solution indicates only a trace of grape sugar.

Cane Sugar. (This should not be tested for, if grape sugar is present.)

To about ½ in. of the extract in a test-tube, add a few drops of hydrochloric acid and boil for a few minutes. By this process cane sugar, if present, is converted into grape sugar. Cool and neutralize the excess acid with sodium hydroxide solution. The test with Fehling's can then be applied.

An orange precipitate indicates the presence of cane sugar.

5. Crush a little coconut or almond between two pieces of white paper. A grease spot will tell you that *fat* is present.

6. Burn different foods. They turn black and dry, and, after the process is continued, a little ash is left. This is *mineral matter*, which cannot be burnt up.

Make a chart of three columns. Write over the first column the word "Food plant," over the second "Part tested," and over the third "Food substances found," and put into the chart the results of your investigations.

Note that we and all other animals live on plants, directly or indirectly, because we cannot manufacture the food substances ourselves and the plants make them abundantly, storing them in root, shoot, flower, fruit, or seed, primarily for their own use.

Hibernation

In the first year such aspects of plant life were studied as testified to the fact that winter is a period of rest. By reading, information from the teacher, and such out-door observations as are possible, children should learn how many different animals as possible hibernate during the winter. Pictures of animals (including always birds, insects, and all other forms of animal life) should be collected and mounted to form class-sheets and reference picture books. Such a collection will be found most valuable throughout the course.

In summarizing and organizing the children's studies of animal life in winter, the subject-matter may be treated as follows—

Consider the approach of winter and how it must affect animal life. See how the animals adapt themselves, in different ways, to these conditions. Adjustment shows itself on an inclined plane from wakefulness to sleep thus. Fox and rabbit show no special adaptation. Mountain hare, stoat, and ptarmigan turn white. Harvest mouse and woodmouse make special stores of food. Squirrel and dormouse make stores and spend much time in winter-sleep. Hedgehog and bat make no stores and sleep all the time. Both winter-sleep and migration are a way of evading the hardships of winter; so is the practice of many people of this country of going to the Riviera and other warm places, while winter lasts.

Birds and their Young

In the course of their studies of animal life in winter, the children will have learnt to recognize resident birds and to become acquainted with some of their habits. The feeding of birds in winter should become a matter of interest, and proper methods of feeding various species of birds should be discussed.

As in the previous year spring was realized to be the season of young things, this concept is now extended by considering the relation of parents to their young and their care and devotion. In order to make this study concrete it may well be carried out on the subject of birds, their nest-building and egg-laying, and their devoted care of their young. A fowl's egg should be examined and the meaning of the various parts understood. The possession of a lantern or perhaps an episcope immeasurably enriches such a study, especially for town children, whose opportunity for observation is so limited. The episcope has the advantage of making the use of magazine cuttings, picture post-cards, etc., possible, and so ensuring a much more extensive supply of pictures.

The Young of Other Animals

Records of observation of the young of school and home pets and of farm animals should be accumulated and the care of the parents for their young specially noted.

Spring Flowers

Flower description will naturally form part of the programme, and the ways in which seed formation is ensured should receive special attention.

IV. 2nd Year: April to October

The growth and development of young animals and plants should form the special study. This involves observations on change in general and metamorphosis in particular.

Life Cycles

The study of living things from egg to egg or from seed to seed is a matter of vital experience for country children, and their written, illustrated, and dated records should represent work of greatest educational importance. But even town children have some opportunity of obtaining the sense of continuity in living things while growth and change proceed. The following plants and animals are known to have exhibited their life cycles in urban schools: nasturtium, Virginia stock, marigold, pea, water snail, caddis, cabbage white butterfly, tiger and magpie moth, silk moth, stick insects.

Life Functions

The work is intended to form a practical introduction to the principles of plant physiology and to supply concrete ideas for the study of similar functions in animals. For guidance in the selection of suitable experiments and necessary

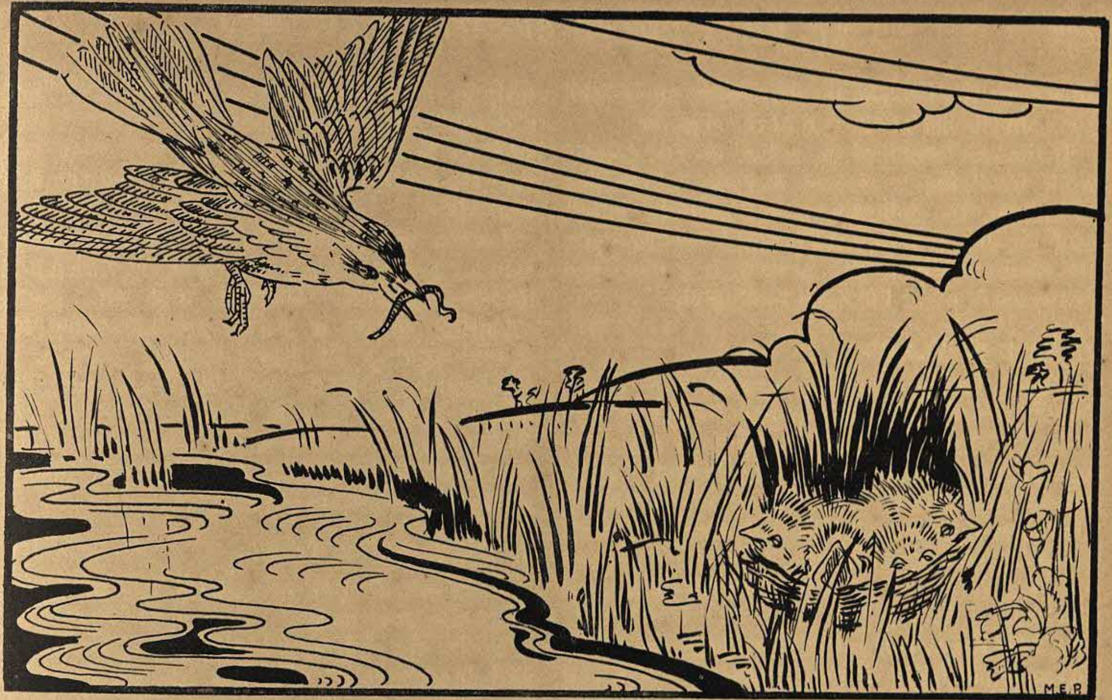


FIG. 11
Bird and Nest

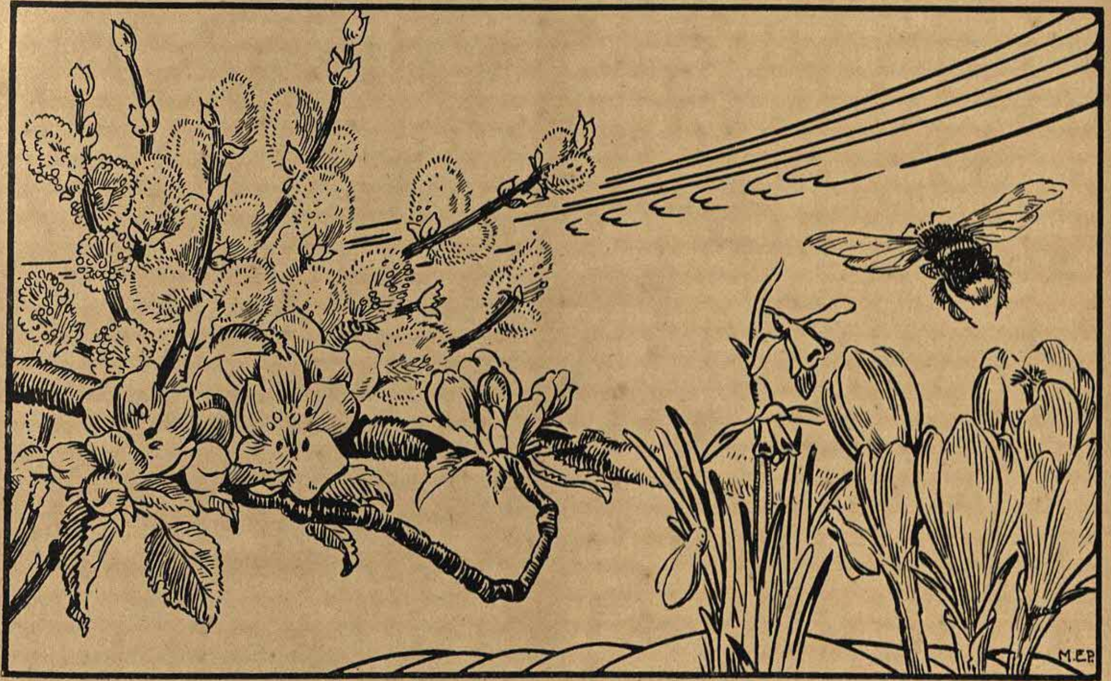


FIG. 12
Spring Flowers

apparatus the teacher should consult one of the books in the list at the end of the chapter.

If the conditions of the school do not permit work involving a certain measure of science technique, the following notes may be found useful in planning some very simple experiments, the results of which may, nevertheless, make the processes of plant life more intelligible.

1. Food of Plants

Starch, sugar, fat, and protein have been found in various storing organs of plants (see p. 169). These substances have been made by the plants out of water and mineral matter dissolved in it in the soil and out of gases in the air. How this is possible is a subject too difficult to understand at this stage, but the following experiments give us some information concerning it—

1. The passage of soil water through the plant. Place some fleshy and some woody stems and stalks of plants, e.g. privet, marrow, celery, narcissus, or a fleshy root (turnip) with the lower end in water coloured pink with red ink. The next day cut these parts across and also lengthways and note the path of the stream upward.

Put a clean glass jar over a leafy shoot. Plug up its mouth with cotton-wool. The moisture which appears inside the jar has probably escaped from the leaves; this is certainly true if another jar arranged in the same way, but without a shoot, remains dry.

Mix some water with soil, filter and compare this soil water which the plant takes in with the water which is given out by the leaves.

Get some small bottles and fill some with soil water and others with distilled water. Grow a seedling plant in each and see how they thrive.

2. The green leaf can make starch in the sun. The children know how to detect starch (see p. 169). Leaves may be tested for starch, but the green colour obscures the reaction. Decolourize leaves by placing them in methylated spirit, gently warming this in a water bath over a low flame. The leaves become almost white, the green colour having been dissolved out by the methylated spirit. The leaves can now be tested with iodine. Notice the difference in result when leaves are picked in the afternoon of a sunny day, and when they are picked very early in the morning or have been covered back and front with black paper. We conclude that sunlight is necessary for starch formation and that starch is evidently removed from the leaf over night.

Leaves which are not green cannot make starch. Test this statement by using variegated leaves. Evidently sunlight and the green colouring matter of leaves are necessary for starch making. In starch-making carbon is captured from the air and this is necessary for protein and fat as well. We come to the conclusion, therefore, that all the food stores of the world, which animals and plants need, depend on the sun and the green leaf.

2. Breathing of Plants

Find out all you can about the breathing process in your body.

Notice any difference in the air you breathe in and breathe out. Chemists provide us with lime-water for this experiment. Blow ordinary air such as we breathe into some lime-water by means of a pair of bellows. It remains clear. Blow your breath through a glass tube or straw into it. It will become milky. See if plants need air. Take a jar and put some earth in it and press it well down. Sow some seeds in it. Press down more earth and again sow seeds. Repeat and cover the top layer of seeds only lightly with earth. Water. Note that only the top seeds grow—the others had practically no air. It is important to hoe and dig in the garden to let air into the ground.

Fit glass jars with corks or cardboard lids. Hang a bag of mosquito netting from the cover into each jar and fill one bag with germinating seeds, another with a growing bulb or tuber, another with buds, another with flowers. Keep lime-water at the bottom. The milky lime-water tells you that they breathe.

V. 3rd Year: October to April

Fading and dying among animals and plants.

A lesson may well be given on short-lived and long-lived animals and plants. The characteristics of annual and perennial plants may be studied. Once more the trees receive attention and their bark is found to be another means of identification. Bark-prints may be made by way of records of observations. To do this proceed as follows—

Lay a piece of white paper, about the thickness of newspaper, over the part of the bark chosen and fix it down with drawing pins. With a lump of cobbler's wax (heel ball) rub firmly and evenly up and down the paper. When the bark pattern has appeared on the paper, take it off. No one could describe the bark as well as this print. The children could tint the print with a wash of the same colour as the bark and so make the picture complete.

Autumn Leaves

Once more the beauty of the coloured autumn leaves stimulate artistic expression. Carbon prints of leaves are like fine pencil drawings and require skill in the preparation. Choose some perfect leaves which have clearly marked veins at the back. Oak, beech, and lime give good results. Hold a plate over a lighted candle and let it get black with plenty of candle soot. Put a tiny drop of oil in the soot and mix it up. The amount of oil should only be sufficient for the particles to cling together, not to make a paste. Lay the leaf on a sheet of newspaper and with a pad of soft paper rub some of the black mixture all over the back of the leaf. Put the leaf with the black side downward on a piece of clean, white paper. Rub the leaf evenly with the finger tips. Lift up the leaf and there should be a fine print of it on the paper.

Observations should be made on the characteristic autumn colour of different leaves. Leaf-fall may now be discussed in the light of the fact that the activities of the root are diminished and a period of rest begins, during which it is necessary to conserve the supply of moisture.

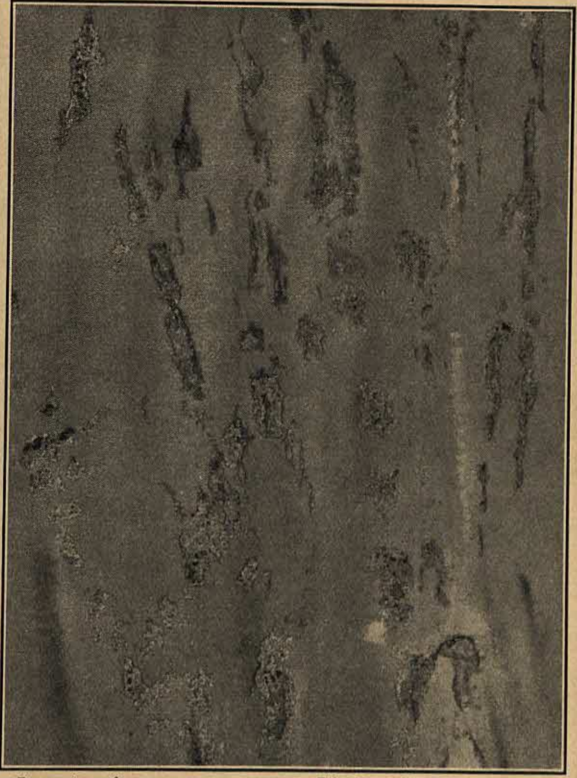
Toadstools, Moulds, and Leaf-mould

The work of moulds and toadstools in the disintegration of leaves is an important biological fact. The life-history and structure of these fungi should be studied.

The work of bacteria causing dead things to decompose and return to dust.

The Soil

Samples of soil may be dried, examined and a list made of the ingredients. The ingredients in a sample of soil may be separated by stirring it up in water and decanting the liquid off repeatedly. The ingredients are decayed vegetable or animal matter (humus), gravel, coarse sand, fine sand, and clay. Sometimes the soil also contains chalk. The capacity of different soils to hold water and air should be determined experimentally and also their capillarity.



By courtesy of *The School Nature Study Union*

FIG. 13

Bark Prints

Earthworms and their importance in nature should be discussed during this study of the nature and structure of soil.

Lessons on earthworms contain scope for observation and experiment, easily within the compass of the children.

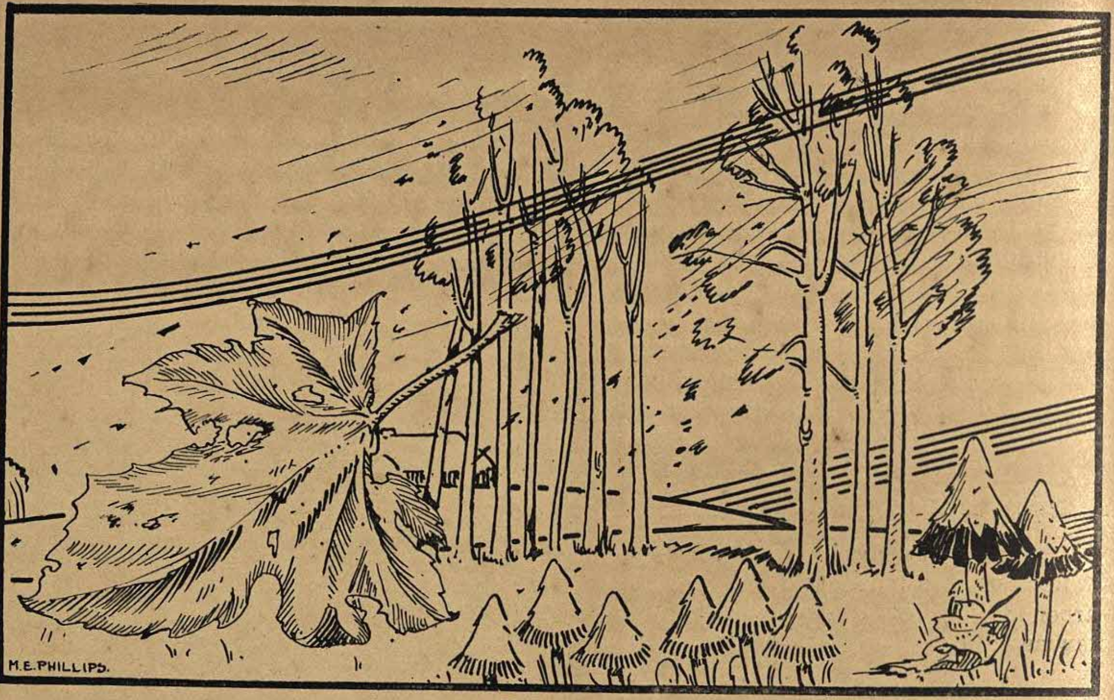

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FIG. 14
Autumn Leaves

FIG. 15
Moulds

CONCLUSION

VI. 3rd Year: April to October

During this last period of the children in school life, their work in biology should consist in the application of their knowledge to an understanding of the wider issues of life. Some demonstration with the help of a microscope is essential and a micro-projector is invaluable for class instruction.

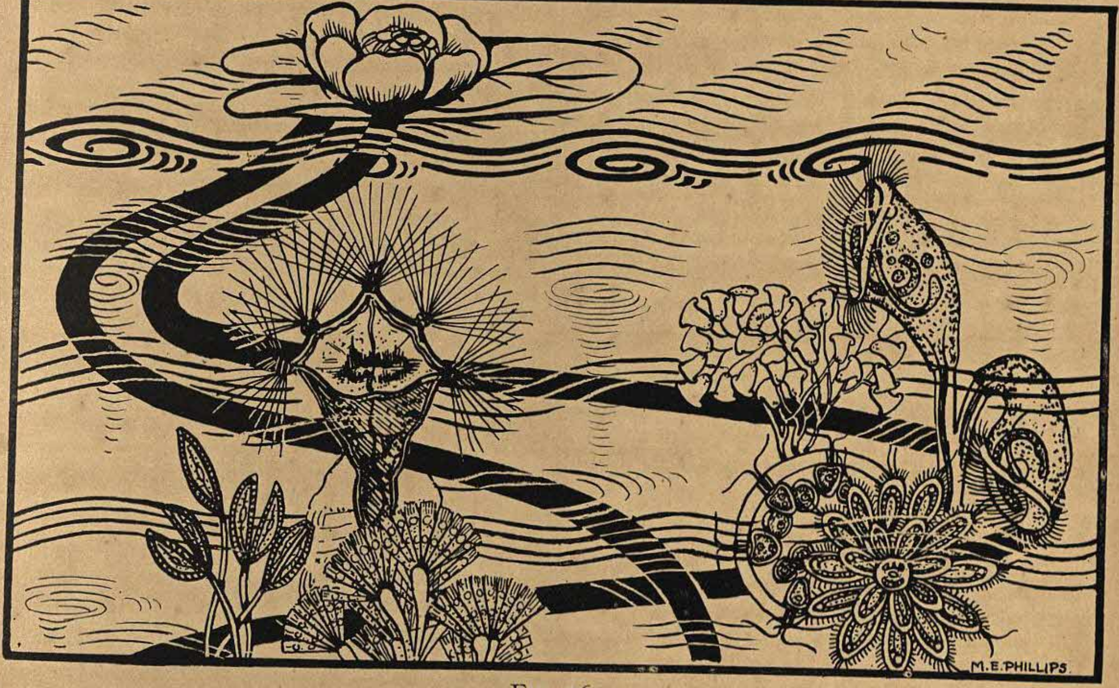


FIG. 16

Wonders of Microscopic Life

The following topics should receive attention—

How living things may be distinguished from non-living. Fundamental unity of living things as regards function and structure. Cell, tissue, organ. Examination of a living water-flea (*Daphnia*) in which, with the help of the microscope, organs may be seen at work. Simple classification of animals and plants according to structure. Development (chick embryo, embryo of water snail or of caddis) in broad outline. What is meant by inheritance and how the latter is affected by environment.

The work has been described in barest outline within the narrow limits of this book. Teachers who are not yet sufficiently experienced to put substance into this scheme are advised to consult books providing the subject-matter and necessary biological information. For this purpose a short list of directly useful books is appended. The gains for the pupils of the teacher who carries out this course in the spirit already indicated should be—

1. Close and direct contact with nature and re-creative enjoyment.

2. A realization of the universal facts of life. They should understand the characteristics of living things, viz.—

They come into the world.

They feed.

They breathe.

They make the best of conditions.

They become parents.

They provide for their young.

They grow and change.	They are related to each other and to the rest of their surroundings.

3. The adolescent child will have become familiar with the big facts concerning the continuance of life in the study of animals and plants, and it may be left to their intelligence to see human and personal applications.

Nature-study Books

BOOKS ON GENERAL NATURE STUDY AND ELEMENTARY BIOLOGY

The Aims and Methods of Nature Study, J. RENNIE (University Tutorial Press). (Price 4s. 6d. or 5s.)

This book is a very useful guide for teachers. It deals with general principles and methods and it supplies outlines for schemes of work. The greater part of the book contains studies of animal and plant life with suggestions to the teacher as to procedure.

School Lessons in Plant and Animal Life, J. RENNIE (University Tutorial Press). (Price 4s. 6d. or 5s.)

Interesting lessons on well-chosen subjects. Allows sufficient scope for the individuality of the teacher.

Biology of the Seasons, SIR J. ARTHUR THOMSON (Andrew Melrose). (Price 10s. 6d.)

A most inspiring work on seasonal biology dealing with seasonal changes among living things and phases of life in animals and plants. This book is at present out of print, but a cheaper edition is likely to be issued, and second-hand copies may be obtained.

Elementary Biology for Matriculation and Allied Examinations, M. E. PHILLIPS and L. E. COX (University of London Press). (Price 6s.)

This book is useful wherever biology is studied as a cultural subject. The general biological principles are set forth by means of an extensive series of carefully selected animal and plant types.

A First Book of Biology, M. E. PHILLIPS and L. E. COX (University of London Press). (Price 6s.)

A simply written book serving as an introduction to the more advanced volume. It represents the less formal nature-study approach to biology. Very accurate and interesting.

Plant and Animal Life, R. F. SHOVE (Methuen & Co. Ltd.). (Price 5s. 6d.)

This book is intended to give a knowledge of the chief life processes in plants and animals and some understanding of general biological principles. It follows the type method in order that the pupils may realize the plant or animal as a living whole. It contains suggestions for practical work.

Elements of Biology, C. VON WYSS (Christophers). Part I and Part II in one volume. Price 4s. 6d. Part I alone. Price 2s. 6d.

Deals with living creatures in the seasons of the year and first biological principles. It is intended for use by the pupils, but will also serve the teacher as a guide in the arrangement of subject-matter and in establishing a definite point of view.

Easy Experiments with Plants, HERBERT MCKAY (Oxford University Press). (Price 2s.)

The experiments are very simple, requiring no elaborate apparatus, and may serve as a basis for practical nature-study.

BOOKS ON SPECIAL SUBJECTS

An Introduction to Zoology, R. B. LULHAM (Macmillan). (Price 10s. 6d.)

A series of nature-studies dealing with invertebrate animals and treated from a biological point of view. The author is a naturalist of first rank and has much insight into her subject and into the needs of students and teachers.

The Outdoor World Series, W. FURNEAUX (Longmans, Green & Co.). (Price 4s. 6d. or 5s. each.)

A series of handbooks of a reliable kind providing practical help in the study of animals and plants out of doors.

Life in Ponds and Streams and *The Sea Shore* are particularly useful.

The Wayside and Woodland Series, E. STEP (Warne & Co.).

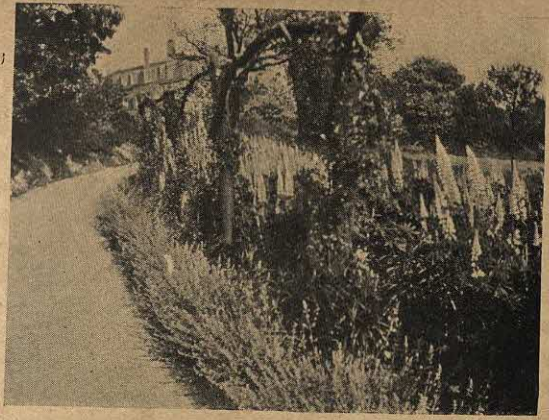
The books are most useful for identifying plants and animals. They are interesting, well written, and excellently illustrated.

Living Creatures, C. VON WYSS (A. & C. Black). (Price 10s. 6d.)

Detailed studies of common forms of animal and plant life providing material for lessons.

Science in Everyday Life Series (Pitman), e.g. *Science and Living Things* (2s. 6d.), *Wonders of the Earth's Crust* (2s. 6d.), *Science in the Country* (2s. 6d.), *Science and the Weather* (2s. 6d.).

Pupils' books, the underlying idea of the series being to teach scientific principles through common objects and contrivances. Plenty of scope for simple experimental work is provided.



GARDENING

THE AIM OF SENIOR SCHOOL GARDENING

THOUGHTS about the school garden might well begin with a mental picture of what it should *not* be.

We see a flourishing allotment—the more "paying" vegetables arranged according to a scientifically planned rotation—not a line out of the straight. We see a class of embryo market-gardeners (boys) learning how to make the land pay—we see them growing only those crops most wanted in their home larders in order that a certain sum of money may be realized annually from the sale of their produce. No girls—no flowers—no space for crops that "do not pay"! No space for untidy, unproductive experiments!

Now, although much may be learnt from such an allotment, it is the *least* valuable type of school garden. A definite break away from *market*-gardening is necessary if children are to make the best possible use of a plot of land.

The ideal school garden should be cultural, not vocational; educational, not commercial. There should be room in it for a considerable variety of easily grown, interesting plants of all types, many of which could not possibly "pay." There should be space in it for untidy experiments.

The form of it will vary and different plants be grown in different schools. Great elasticity of treatment will be necessary if we are to get the best results from shady as well as sunny sites, small as well as large gardens, and from all types of soil.

There can be no such thing as a "standard" school garden, yet the *aims* of all school gardening should be the same, as indicated in the following paragraphs.

Introduction to Natural Science

In their garden, the pupils should meet with numerous plants and creatures of different types. They should be able to watch the life-cycle of annual, biennial, and perennial plants; of shrubs and herbs; of caterpillars and *aphis*. They should learn how plants are propagated by seeds, bulbs, corms, rhizomes, runners, etc.; by the striking of cuttings; and perhaps also by budding and grafting.

They should observe the food larders in Pea and Bean seeds, in Potato tubers, in the root-stock of a Turnip, the bulb of an Onion, the root of a Carrot.

They should tame birds and make pets of caterpillars.

They should study the weather, and, particularly, the influence of weather upon soils and plants.

They should, by observation and by experiment, learn much about the effects of light, air, warmth, and water upon the growing plant.

For the first aim of school gardening should be to give the child opportunities to learn for himself or herself, by actual outdoor contact with growing plants and animals, something of the working of the laws of God.

Preparation for Life

School gardening should help the mind and spirit of every child. Mere parrot-learning from horticultural text-books does little but train the memory; but real gardening demands attentive observation, scientific reasoning, foresight, much patience, ability to adapt oneself quickly and sensibly to perpetually changing conditions. It fosters initiative and develops a sense of personal responsibility; it teaches the need for public-spirit by showing the power of co-operation. It leads to reverence for and love of order, law, and beauty, and it is a straight way to deep happiness—it is amongst "the purest of human pleasures."

FIG. 1

Beauty which is not Costly

Lupins and Catmint. An alternative arrangement is shown in the left-hand head-piece, page 177

It is a powerful kind of "education for leisure," which is admitted to be specially necessary in the world of to-day.

Outdoor Laboratory, Workshop, and Storehouse

Innumerable scientific experiments can usefully be performed in the school garden, and abundance of material produced in it for Biology, Art, and Handwork lessons. Flowers and fruits with large parts, easy to draw and to dissect, belonging to the more important Natural Orders, should be grown; but scattered about naturally all over the garden, in the borders, seed-plots, shrubbery, fruit-plot, etc., rather than segregated in a so-called "Botany Garden." The garden should produce specimens of underground-stems of all kinds, useful weeds like Shepherd's Purse, useful caterpillars like those of the Gooseberry Magpie Moth.

A few plants should be specially grown for their value as botanical material. Sunflowers, for instance, are useful at all stages of their growth. The young shoots are good for work on the cell, the growing leaves are excellent for transpiration experiments, and both flowers and seeds are useful too.

For Drawing and Painting lessons should be grown a succession of flowers not white, not double, and not very small. Roses with big hips should not be forgotten, nor the Stinking Iris, for the sake of its brightly coloured autumn fruits.

Then why not some dye-plants for the Handwork pupils? One Elder bush will provide berries enough for a good brew of dye, and Onion skins yield one of the most useful tints.

Arithmetic will acquire a new interest if the pupils do necessary sums as they arise in garden practice—

Fourteen pounds of seed-potatoes cost three shillings. What will it cost, approximately, to plant two rows across a plot three yards wide if the tubers are set one foot apart? What would it cost to plant the *whole* plot with Early Potatoes if the rows were two feet apart? Here the dimensions of the plot have to be got by measurement, the average number of Potatoes to the pound determined, and several calculations done—a *real* sum this, not a text-book example!

Sulphate of ammonia may be given to the school grass at the rate of 1 oz. per square yard. If three such dressings are to be given during the year, the approximate amount of the fertilizer required should be found out by the children, with the total cost of the operation.

Geography pupils can learn something of ecology in the garden, too.

For the school garden should be a catholic place, of use to the whole school—the very home of correlations.

Aesthetic Training Ground

It should also be a beautiful place. Colours should be chosen to blend, not clash; form should be studied and jerky spot-and-dot grouping avoided. Beauty need be no more costly than ugliness, and some of the loveliest arrangements need include only the cheapest and hardiest of "common" plants.

May Tulips, "Clara Butt" and "Rev. Ewbank," are exquisite near Lilac, "Souvenir de Louis Späthe," and cost no more than other Tulips and Lilacs.

The clear, pure blue of *Nemophila insignis* is at its loveliest near the pale yellow of *Limnanthes Douglasi*: both are easy annuals.

A riot of common Nasturtiums near Red-hot-pokers, *Helenium*, and *Montbretia*, is like an imprisoned sunset.

There should be many such pictures.

And it should never be necessary to plant rose-pink or puce flowers immediately in front of the raw red bricks of a new school, as is, alas! sometimes done; or next to yellow Marigolds.

LAY-OUTS AND LISTS FOR SCHOOL-GARDENS

Schools with large grounds can choose between laying out a special school garden in one place or letting the children work everywhere.

In some new schools the grounds are too large to be cared for properly by children and teachers alone, so part of the work is done by a professional gardener or by the caretaker. As dual control may easily lead to friction, it is better, in such cases, to separate entirely the educational school garden from the rest of the grounds; or else definitely to arrange which bits are to be worked by the man and which by the children.

Lay-out of a Special School Garden

A special school garden should have unity of plan; should be, if possible, pulled together by a central gathering-point where the children can meet for instruction and discussion.

This might consist of a small square lawn; of a court of crazy-paving, home-made tiles, or old bricks; or of a gravelled space. In the centre there might be a combined bird-table and bird-bath, or else a sundial.

There should be some narrow oblong seed-plots round this, for small groups of children to work. Where there is enough space, two children should share a plot, as then much valuable individual work can be done. In smaller gardens it will be necessary for three or four children to work a plot, and sometimes one or two plots may have to be shared by the whole class.

In the ideal garden there should also be a wide herbaceous border with Rambler Roses on poles towards the back of it, a fruit-plot, a rockery, a shady border for bulbs and ferns, a nursery with a small cold frame in it, an experimental-plot, and space for weather-apparatus.

None of these features need be large, and if space is limited some can be merged into others. The herbaceous border might, for instance, have its shady end reserved for bulbs, turn into a rockery at its sunny end, and have dwarf fruit bushes at the back of it.

Exact dimensions will vary from school to school. Measurements are not of importance, but the children's seed-plots should be narrow enough for much weeding and thinning-out to be done from the boundary-paths.

So often it is fine enough to work outdoors when the land is too wet to be trodden upon: on such a day two children can reach over almost the whole of a plot that is only six or eight feet wide.

The Natural School Garden

If the children work all over an extensive piece of ground, the "features" recommended for the special garden will be found in their natural positions or can easily be fitted into suitable places. There will be a lawn and shrubberies, flower-borders, both sunny and shady, and space for a small rockery. The seed-plots, fruit-plot, the nursery and experimental beds, will go best into the vegetable garden. If there is not one, then part of a border must be used for them, or some large flower-beds be adapted or even a slice off a lawn.

This kind of garden is more difficult to teach in, as the children are more scattered than in the special school garden. Also, it is easy to waste time in it, in getting from place to place, unless the teacher is a very good organizer. But it can be made more beautiful than the special garden, and calls for greater ingenuity from the teacher. It will have odd corners, walls, steep banks, perhaps; and all these can be adapted to serve the needs of the children. For instance, if there are walls all the fruit needed could be grown upon them.

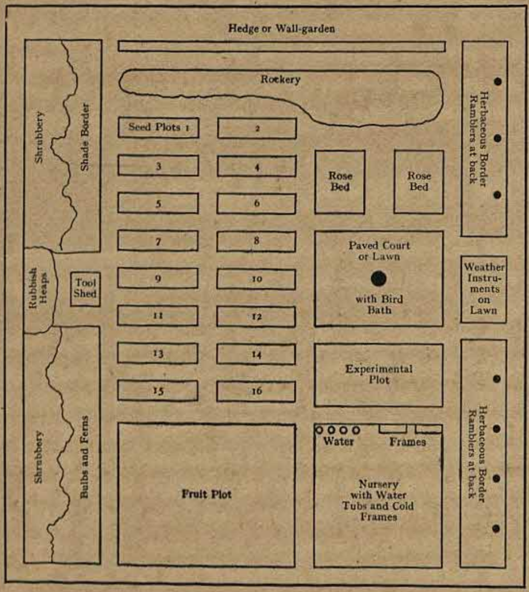


FIG. 2

Plan of large School-garden

Contains Seed Plots for two divisions of sixteen children—two children sharing each Plot. Shade Borders face north: Herbaceous Borders south.

In awkward, shady corners under trees a beautiful wild garden could be made with bulbs.

A steep bank could easily be turned into a rockery.

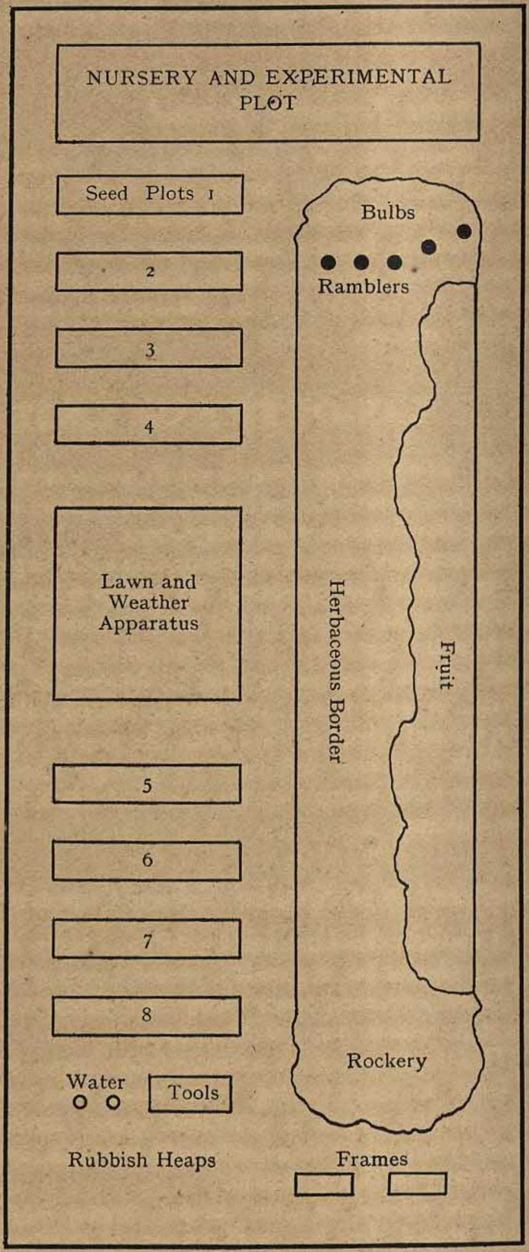


FIG. 3

Plan of small School-garden

Contains Seed Plots for two divisions of sixteen children—four children sharing each Plot.

Choice of Plants for School Gardens

Except those on difficult sites—which will be considered later—every school garden should contain some fruit, some shrubs, herbaceous perennials, annual and biennial flowers, bulbs and corms, rock-plants, vegetables, and a little grass.

The choice of kinds and varieties is of the very greatest importance.

Suitable kinds are no more trouble to grow and need cost no more than unsuitable kinds, yet in school after school one sees valuable space filled up with rubbish.

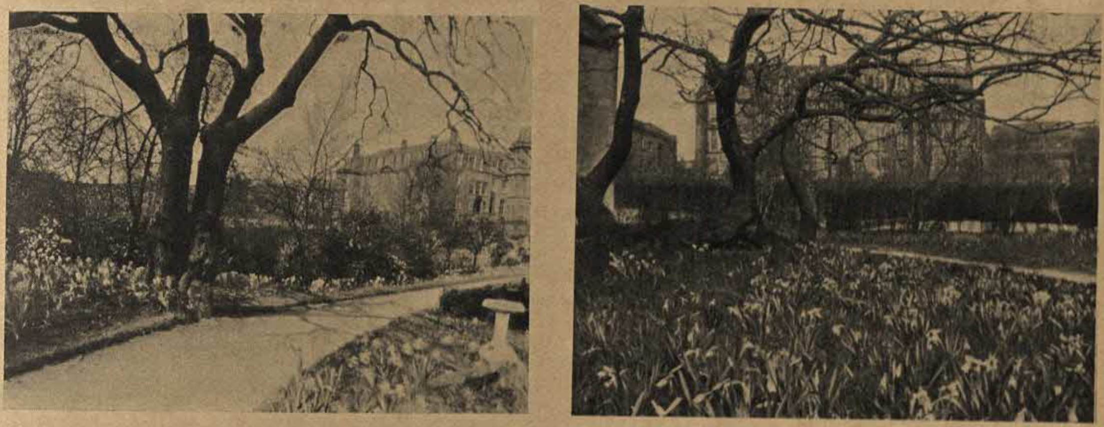


FIG. 4

"A Beautiful Wild Garden could be made with Bulbs"

Certain considerations limit the choice of plants for *schools*—

(*a*) *Crops are not wanted which are ready for use during school holidays.*

"Dorothy Perkins," "Crimson Rambler," "Lady Gay," etc., are at their best during August, when, in many schools, children are away on holiday. Yet they are commonly planted instead of the early-flowering Rambler Roses, such as "Alberic Barbier," which come out during the Summer Term.

Runner and French Beans are wasted in schools, unless sown unusually late, as they, too, are ready in August.

Extra early and extra late Daffodils should be chosen for *outdoor* planting in schools, as most of the maincrop varieties bloom at Easter.

(*b*) *Crops are not wanted all at one time.*

A school garden should provide work for the whole year and a *succession* of crops. It is not enough merely to avoid waste during holidays.

We should also avoid a glut of specimens at one time and famine for most of the rest of the year—which often happens when too much attention is paid to the growing of hardy annuals. These make a fine show in July, but there may be nothing out in early May and late October; whereas if some carefully chosen bulbs, shrubs, and spring- and autumn-flowering herbaceous perennials are grown, and a few biennials sown, the garden need seldom be bare.

(*c*) *The school garden should contain nothing dangerous to children.*

Some poisonous plants, such as Foxglove, are unlikely to harm a child; but Laburnums have attractive but dangerous fruits, and the root of Monkshood is so like Horseradish that it has been mistaken for it with fatal results. Dangerously poisonous plants, together with all poison sprays and weed-killers, and corrosive forms of lime, should be barred from grounds in which children work.

(*d*) *Hardy crops should be chosen to suit the soil and the site.*

There should be no room in the school garden for delicate, difficult plants; and it is a pity to put clay-lovers on sand, sand-lovers on clay, sun-lovers in shade, lime-haters on chalk. . . .

Lists of Varieties

GROUP A. HARDY PLANTS FOR HERBACEOUS BORDERS—IN ORDER OF FLOWERING

TALL. *Doronicum,* May-flowering Irises, Lupins, Oriental Poppies, June-flowering Irises, *Anchusa italica* "Dropmore," Shasta Daisies (*Chrysanthemum leucanthemum*), *Anthemis tinctoria* "Buxton's Variety" (a most useful lemon Marguerite), Golden Rod "Golden Wings," Michaelmas Daisies, *Helenium,* Red-hot-pokers, and Hardy Border Chrysanthemums in single varieties.

MEDIUM HEIGHT. Perennial Cornflowers, Columbines, *Veronica incana* and *V. spicata, Erigeron,* single *Geum* or *Potentilla,* Canterbury Bells, Sweet Williams, Dwarf Michaelmas Daisies (especially "King George"), *Montbretia,* and Japanese Anemones.

SHORT. Christmas Rose, *Arabis, Polyanthus, Myosotis,* Rock Viola (*V. cornuta*) and Bedding Violas, London Pride, Thrift, Single Pinks and *Allwoodii, Cerastium,* Catmint (*Nepeta Mussini*), and Creeping Jenny.

On heavy soils Delphiniums might be added to this list, on light soils Tree-lupins.

GROUP B. PLANTS FOR SHADY BORDERS—IN ORDER OF FLOWERING

TALL. *Doronicum,* May-flowering Pæonies and Irises (Single Pæonies are most useful), June-flowering Pæonies and Irises, Mulleins, *Iris Sibirica, Thalictrum,* Evening Primroses, *Campanula persicifolia,* Golden Rod, and *Helenium.*

MEDIUM HEIGHT. Solomon's Seal, *Tradescantia,* Columbine, *Polemonium, Trollius, Heuchera, Primula Japonica,* Canterbury Bells, Foxgloves, *Astrantia,* Honesty, *Montbretia,* and Japanese Anemones.

SHORT. Christmas Rose, Periwinkle, *Arabis, Polyanthus, Myosotis,* Mossy Saxifrages, London Pride, Lily-of-the-Valley, *Auricula,* Joseph-and-his-Brethren (*Dicentra* or *Dielytra eximea*), *Viola cornuta,* Pansy, *Iberis, Cerastium,* and Creeping Jenny.

GROUP C. PLANTS UNSUITABLE FOR SCHOOL BORDERS

Hollyhocks, *Phlox decussata, Gaillardia, Sidalcea,* and Monkshood.

GROUP D. SHRUBS FOR HEAVY SOILS

TALL. Lilacs "Souvenir de Louis Späthe" and "Charles X." (purple) — also "Marie Legraye" (white), *Philadelphus* (Mock Orange), *Viburnum* (Snowball Tree), Elder (for dye), and *Weigela.*

SHORTER. *Daphne mezereon, Pyrus Japonica* grown as a bush, Flowering Currant, *Berberis aquifolium,* and *Hypericum* (very dwarf).

GROUP E. SHRUBS FOR LIGHT SOILS

MEDIUM. Brooms, Bladder Senna, Flowering Currant, *Berberis* in variety, *Rosa rugosa, Spartium junceum,* Sea Buckthorn, Snowberry, and *Olearia Haastii.*

SHORTER. Polyantha Rose "Pink Delight" (very useful single variety—seldom out of flower), Lavender, and Rosemary (not in the North).

GROUP F. SHRUBS *Unsuitable* FOR SCHOOLS

Broad-leaved Evergreens, such as Laurels, are particularly unsuitable for town gardens and colliery districts.

GROUP G. SMALL TREES FOR SCHOOLS

Damson, Bullace, Crab-apple, Single Hawthorn, White Beam, Silver Birch, and Mountain Ash.

GROUP H. TREES *Unsuitable* FOR SCHOOLS

Large forest trees are unsuitable in any but very large grounds, as they block out light and impoverish soil. Laburnum is poisonous.

GROUP I. RAMBLER ROSES FOR SCHOOLS

"Alberic Barbier," "Jersey Beauty," and "Gardenia" (cream); "François Juranville," "Leontina Gervaise," "Renée Andrée" (salmon); "Shower of Gold," "Emily Gray" (yellow); "Carmine Pillar" (red); "Mrs. Flight," "Blush Rambler," "Tea Rambler" (pink). In the south, the exquisite lemon variety called "Mermaid" may be added: its enormous single flowers are very useful.

GROUP J. RAMBLERS *Unsuitable* FOR SCHOOLS

"Crimson Rambler," "Dorothy Perkins," "White Dorothy," "Dorothy Dennison," "Excelsa," "Lady Gay," "Hiawatha."

GROUP K. SOME VERY HARDY ROSES

"Caroline Testout" (pink), "Gen. McArthur" (crimson), "Christine" (golden), "Emma Wright" (orange). Some good single varieties are: "Isabel," "Irish Elegance" (pink), and "Irish Fireflame" (orange). Also the dwarf Polyantha Rose "Pink Delight."

GROUP L. GOOD WALL PLANTS

Cordon Apples and Pears, Stone-fruit, and Red Currants as fans, Gooseberries as fans, *Pyrus Japonica*, Roses "Gloire de Dijon" and "Reine Marie Henriette." Gooseberries and Rose "Gloire de Dijon" will do on a North wall.

GROUP M. PLANTS *Unsuitable* FOR WALLS

Rambler Roses, Raspberries, Loganberries, Blackberries, and Black Currants should not be used on walls unless they can be tied to wires run through staples or to trellis-work.

As old wood has to be cut out and new wood put in its place annually, the "pointing" of walls is seriously damaged if this type of plant is nailed to them. Jasmines and Honeysuckles attract flies, darken windows, and are very untidy. *Ampelopsis* smothers the "lines" of a good building and encroaches on windows.

GROUP N. GOOD HEDGE PLANTS

Beech (heavy soil), *Rosa rugosa* (light soil), *Lonicera nitida* (any soil).

GROUP O. SUN-LOVING BANK AND ROCKERY PLANTS

Arabis, *Aubrietia*, *Alyssum*, *Auricula*, *Phlox subulata*, *Viola cornuta*, Thrift, Creeping Veronicas and Thymes, *Helianthemum*, Rock Pinks, *Dryas octopetala*, Catmint, *Centranthus ruber* (Valerian), *Cerastium*, and *Polygonum persicaria*.

GROUP P. SHADE-LOVING BANK AND ROCKERY PLANTS

Primula denticulata, *Auricula*, Periwinkle, Coloured Primroses, London Pride, Lily-of-the-Valley, Mossy Saxifrage, *Viola cornuta*, *Arenaria balearica*, *Iberis*, *Cerastium*, Creeping Jenny, and Ivy (not in smoky places).

GROUP Q. FRUITS FOR SCHOOLS

In most districts Apples are likely to do better than Pears. If only one tree can be grown it should be a self-fertile variety or no fruit will set. "Lord Grosvenor" is a good early cooking Apple, "Newton Wonder" an excellent late one. "Pott's Seedling" does well in towns. "King-of-the-Pippins" is a good dessert sort. *All these varieties are self-fertile.* Siberian Crab Apples are just as useful in schools as the large kinds: they are valuable for Art lessons.

Good self-fertile October Pears are "Conference" and "Durondeau." Most Plums ripen in August and will not keep, but "Monarch" ripens later and is a good self-fertile cooking variety. Cherries are likely to be stripped by birds unless grown on a wall and netted. "May Duke" is a good self-fertile sort.

Damsons and Bullaces are extremely useful stone-fruits for schools: they are very hardy and ripen late.

The Gooseberry should be in every school—if only for the caterpillars it attracts—so should Raspberries or Loganberries or Blackberries, and a Black Currant as well as a Red Currant.

Dessert Strawberries only do well on clay soils, but the glorified Wild Strawberries called "Red Alpine" and "St. Anthony of Padua" flourish everywhere. They can easily and quickly be raised from seed, take up less room than large sorts, and have a special fascination for children.

GROUP R. VEGETABLES FOR SCHOOLS

Quickly maturing and dwarf varieties are amongst the best for schools. "Early Nantes" and "Early Shorthorn" are good Carrots and "Early Snowball" the best of the Turnips. "French Breakfast" is an excellent Radish.

"Sharpe's Express" is a dependable Early Potato. Jerusalem Artichokes are too big for children's plots, but are sometimes useful in odd corners or to screen a rubbish-heap. Amongst leaf-crops, some kind of Cabbage *must* be grown, if only to encourage Cabbage White Butterflies! The quick-hearting sorts should be chosen, and they should be sown in Spring, not in Autumn. "Flower of Spring" is satisfactory. Coleworts are useful because they mature quickly and take little room.

Late Winter-greens should NOT be grown: they hinder the winter digging of the children's plots; and, in towns, become extremely dirty. Varieties should always be selected which can be harvested before November. The hardy little Cabbage Lettuce "All-the-Year-Round" is excellent, though all Lettuces are good. Ordinary Spinach can usefully be grown on stiff soils, but should not be attempted on light soils—where Spinach-Beet (sometimes called Perpetual-Spinach) will grow instead.

A few Brussels Sprouts should be grown for buds, any kind of Onion for its bulb, and either Cauliflower or Early Broccoli for flowers.

Leeks or Chicory or Endive should be grown for blanching: Celery is too difficult. Mustard and Cress, Land Cress, Parsley, and Corn Salad are invaluable for small gardens.

Amongst seed-crops, Broad Beans are useful: they mature early, are hardy, have large parts and harbour an interesting pest called Black Fly.

The Pea selected should be the dwarf and very early "Little Marvel."

French and Runner Beans should not be grown unless sown in June instead of in May, so that the crop is not wasted in August.

GROUP S. FLOWER SEEDS FOR SCHOOLS

Hardy perennials easy to grow from seed are—Lupin, Shasta Daisy, *Anchusa*, Columbine, *Myosotis*, Button Daisies, *Primula Japonica*, *Delphinium formosum*, and Broom (a shrub).

Easy biennials and short-lived perennials are: Wallflower, *Cheiranthus Allioni*, Canterbury Bells, Sweet Williams, Foxglove, Mullein, Evening Primrose, and Honesty.

The best hardy annuals are—

TALL AND MEDIUM. Cornflower, *Nigella*, *Eschscholtzia*, Shirley Poppy, Scarlet Linum, *Calendula* (Marigold), *Bartonia*, and Sweet Peas.

SHORT. Virginian Stock, *Nemophila insignis*, *Limnanthes Douglasii*, Candytuft, *Viscaria*, and Mignonette.

Useful half-hardy annuals are: Giant Sunflower (for Botany), Canary Creeper, Climbing and Dwarf Nasturtiums, and Single Asters. If sown in May these can be treated as hardy.

The following annuals are so likely to be at their best in August that they should be AVOIDED in schools—Clarkia, Godetia, Nemesia, Larkspur, and Annual Phlox.

GROUP T. BULBS FOR SCHOOLS

For rockery-pockets. Winter Aconites, Snowdrops, Crocuses, *Scilla Sibirica*, *Chionodoxa*, *Muscari* (Grape Hyacinth) "Heavenly Blue," and Autumn Crocuses.

For bulb-borders. All those named above and also Daffodil "Golden Spur," Daffodil "Grandis," Poet's Narcissus "Old Pheasant's Eye," Garden Bluebell (*Scilla Hispanica*, sometimes called *S. campanulata*), and Star-of-Bethlehem.

For naturalizing in grass. Crocuses, *Scilla Sibirica*, Daffodils "Golden Spur," and "Grandis" and Poet's Narcissus.

For formal beds, tubs, plant-boxes, etc., in sunny places. Any May-flowering Tulips. Some good, cheap ones are: "Clara Butt" (soft pink), "Rev. Ewbank" (soft mauve), "Pride of Haarlem" (vivid carmine), "Golden Crown" (yellow), "Macrospila" (crimson) and "Picotee" (white and pale pink).

As they are likely to be at their best at Easter, Hyacinths, Early Tulips, and Mid-season Daffodils and Narcissi should be AVOIDED for *outdoor* planting in schools: Hyacinths, and most Daffodils are invaluable for growing *indoors* where they bloom in term-time.

Accessories

MANURES AND FERTILIZERS FOR SCHOOLS

Stable manure is less messy than farmyard manure for children's use, and some should be ordered annually, to be dug into the seed-plots.

Steamed bone-flour is a cheap form of phosphatic manure and "right" on all types of soils. Potassic manures should NOT be bought: the wood-ash from the garden bonfire contains all the potash necessary and should be saved and used.

Where there are grass tennis courts, sulphate of ammonia should be ordered.

GROUP V. TOOLS AND SUNDRIES FOR SCHOOLS

Where it is financially possible, each child in the class should have: 1 weeding or hand fork with four prongs and a short handle, 1 trowel, 1 border fork, 1 border spade, and 1 Dutch hoe. So-called "children's tools" should *never* be ordered for pupils over ten years old. They are mere toys and twist and break easily. "Ladies' tools" are little better!

Border spades and border forks, though

lighter and slightly smaller than ordinary ones, are strongly made, as they are intended for the use of professional gardeners.

Hoes, weeding forks, and trowels for children should be full-sized ones.

The class should also possess a few draw-hoes, watering cans, weeding baskets (easily made of wood or cane by Handwork pupils), birch-brooms, and small wheelbarrows or a trek-cart—such as Boy Scouts use; also some pocket knives and one pair of sécateurs. Rakes are superfluous. No insecticides, weed-killers, etc., should be requisitioned. Soapy water will do to fight a plague of *aphis*; larger "pests," such as caterpillars, should be removed by hand and kept as pets. The more animal life-histories that can be studied in connection with it, the more useful will be the school garden.

THE SCHEME OF WORK

The number of children in the class should not exceed sixteen. Other practical subjects in the curriculum can only be taught well to a small group; so the average class should be split into two and one part take Gardening, the other Handwork or some other subject.

The First Year

During their first year of Gardening, children should plant bulbs; plant a perennial herb or shrub; sow seeds of several kinds of vegetables, of annual flowers *and of one or more biennial or perennial flowers*. It is highly important to sow a biennial in the first year in order that the end of its life-history may be studied during the second year.

They should learn how to use tools and to care for them, and the *reasons* for all routine operations. Simple digging should be done and the use of "lime" explained. Theory should, on wet days, follow closely in the wake of practice. For instance, talks on bulbs and corms would be given in autumn; about soils in winter, whilst digging was being done; about seeds in the spring; about the work and needs of green leaves in summer—when the importance of sunshine can be so simply demonstrated by thinning-out experiments; and about flowers and fruits in late summer and autumn.

During the first year children should be helped to *observe*, both by frequent inspections of the whole garden and by being required to keep a detailed garden diary. This book should contain not only records of work and happenings in the school garden, but also notes on happenings in local parks and squares and in private gardens. How many flowers came out last week? Which tree dropped its leaves first? Who found the first caterpillar, and where was it?

Even highly intelligent children often seem curiously blind when they begin to work in a garden, and the first care of the teacher should be *to help them to see*. It is easily done! The difference between the entries made in the second year and those made in the first year in the garden diary of the same child is frequently amazing. The later records are usually so much more full, so much more accurate, obviously so much more a matter of zest and enthusiasm.

It is not really that the garden is more thrilling and busy than it was a year ago. It is simply that the eyes of the child are now open.

The Second Year

In the second year children should plant Potatoes; strike cuttings, both shrubby and herbaceous; and plant out biennials or perennials raised themselves in their first year. They should do double-digging as well as simple-digging, and prune Fruit or Roses or both. They might bud a Rose or graft an Apple, though these difficult operations are better deferred if a third year of Gardening is possible. Leeks, Endive, or Chicory may be blanched now. Strawberry runners should be rooted into a pot, and a Blackberry or Loganberry pegged down to the ground to root from the stem. Pinks or Carnations might be layered.

The children should sow more seeds on the same plot that they worked last year and practise a simple rotation. Something might be learnt about the action of a few of the most important manures and fertilizers; also more about the soil and about methods of improving "bad" soils.

A Possible Third Year

It should be possible for children to "finish off" their plots early in the third Autumn before these are taken over by a new class. They should for instance, be able to see the effects of blanching on Leeks, to pick their Brussels Sprouts and late annual flowers, and lift their Parsnips. In few schools will there be enough land for special plots to be available for Third-year pupils—nor would the majority of children stay at school throughout a complete Third Year. However, much valuable communal work might be done on borders, in rockeries and shrubberies and the fruit-plot. New kinds of seeds might be sown in the nursery and new experiments tried. Budding and grafting might be practised—and perhaps hybridizing. A small hot-bed might be made and forcing done; and, in some schools, it might be possible to grow Mushrooms.

FIRST YEAR'S WORK

I. The First Autumn Term

From the beginning, children should be taught to take care of their tools. A few minutes should be allowed, at the end of each lesson, for the cleaning of tools and tidying of the tool-shed, tool-room, or cupboard. Spades, etc., should either be washed in a bucket of water and thoroughly dried or else rubbed clean with grass.

Pocket knives used for gardening should be sharpened on a hone; garden-lines wound up after use; water-cans left upside-down, not partially full of water. Before holidays, the metal parts of all tools should be greased. The tool-shed should be as beautifully tidy as the classroom. Then, too, children should be early taught to *think ahead*—to foresee what tools and tackle they will need for the work that they are going to do, so that they do not have to return to the tool-shed for forgotten items.

During the first term, individual children should be asked to name tools, etc., that they think they will want and to state why they want them.

This takes more time than the method of simply *telling* the children what to fetch from the tool-shed at the beginning of every lesson—but it is time well spent.

Garden Rubbish

All gardens are untidy in Autumn. There are dead tops in the borders and vegetable plots, and leaves are falling in the shrubberies.

The first thing a child should learn about rubbish is that there is no such thing as rubbish!

The purpose of death, the economy of decay, the order in apparent chaos, should be taught to him (and to her—girls should learn gardening as well as boys) during the ordinary "tidying-up" which takes place in Autumn. Nothing need be wasted.

Dead leaves should be swept up and put in a pit or pile where they can turn into leaf-mould. Other dead stuff should be divided into two parts. Anything which decays slowly, such as shrub-prunings, together with perennial weed roots and everything likely to be infectious, such as potato-haulm, should be burnt. The precious bonfire-ash should be stored under cover before it is rained upon, and its fertilizing value mentioned to the children and discussed more fully later when they apply it to the land. Softer "rubbish" of a non-infectious nature, such as dead herbaceous tops and grass-mowings, should be made into a compost-heap, which should sometimes be turned over and trodden upon to help the decaying process. The children who make the compost-heap in the first Autumn should dig into their own plots the humus from it during the second Autumn and Winter.

Old plant-labels should be collected to be scraped clean and repainted upon a wet day. Plant-stakes should also be collected and stored. Sometimes new ones can be contrived out of shrubby prunings before they are burnt.

Any stones, oyster-shells, bones, etc., thrown out during digging should be collected and later used for draining some damp spot: a word or two might be said about the fertilizing value of bones and oyster-shells.

All "tidying" should be *purposeful*.

Bulbs and Corms

Bulbs and corms can be grown in bowls of fibre or pots of soil in the classroom; in window-boxes, or in boxes or tubs on a roof or in an asphalt playground; in grass under trees; on the fringes of shrubberies; and in beds or borders by themselves or mixed with ferns and carpet-plants like Creeping Jenny. Spring-flowering bulbs should NOT be grown in patches in a herbaceous border. They do not look their best in widely scattered small clumps, and they tend to get hurt when the borders are pricked up after the Autumn tidying.

Nor should they be grown in grass which has to be mown early. It is highly important that their leaves should be allowed to die naturally—*not* be cut short whilst still green—and children should find out the reason.

Probably one of the most useful sites for bulbs in a large school garden is the fringe of a shrubbery or a shady border.

If hardy Ferns or Funkias are planted about three feet apart, the spaces can gradually be filled in with bold clumps of shade-loving bulbs (see Group T for suitable kinds). Then, when their leaves become yellow and untidy, the uncurling ferns cover them up and the bulb-garden becomes a fernery during the summer.

For suitable bulbs for rockeries, beds, tubs, etc., see Group T.

(*a*) WHEN TO PLANT

Early-flowering bulbs should be put in during September and October.

Tulips should not go in until November: their leaves are apt to get damaged by frosts if they appear early. When planting in *soil*, dry weather should be chosen; but planting in *turf* is best done after recent heavy rain.

(*b*) HOW TO PLANT

The proper tool to use is a trowel.

The use of a pointed dibber for the planting of bulbs and potatoes is thoroughly mischievous. A small pointed cavity is left, under the base of the bulb, which fills with rain-water, and so the bulb slowly rots away. Another evil is that the sides of a hole made with a dibber are hard, and the bulb needs a loose, airy root-run.

(*c*) DISTANCES

Most bulbs should be buried once-and-a-half to twice their own depth, measuring from base to shoulder (not to the top of the long *neck* of a Daffodil-bulb), but there are several exceptions to this rule. Snowdrops and Tulips need to be extra deep—at least six inches down, the Tulips a little more—whilst Crocuses should be only just covered with soil.

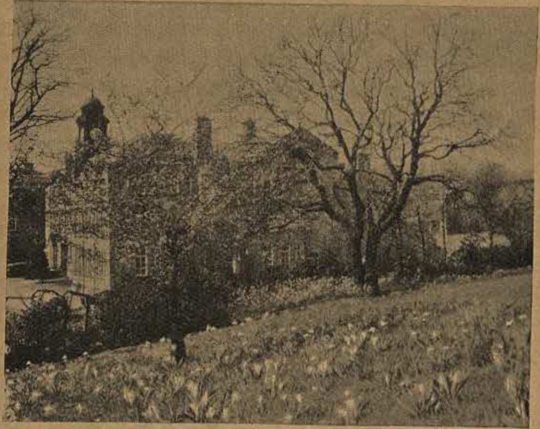


FIG. 5

Bulbs in Grass

"Planted to look as natural as possible . . ."

Large bulbs, such as Daffodils and Tulips, look right about ten inches apart, and tiny ones can hardly be too close together. Winter Aconites, Snowdrops, and Crocuses look well two or three inches apart, *Muscari* and Garden Bluebell four to eight inches. Bulbs in grass should be planted to look as natural as possible—as if they were growing wild.

It is far better to plant a very small area really generously, and increase it a little each year, than to try—in the name of economy—to spread a few bulbs over a large space.

It is important to make notes and a plan of the area planted, or else mark the boundaries of it with sticks, so that one knows exactly where to continue the planting another Autumn. The memory is apt to be treacherous, and it is a pity to plant one lot of bulbs on top of another.

(*d*) AFTER-CARE

All bulbs love potash, so should be top-dressed with bonfire ashes. They also like bone-flour. They do not need or like animal manure.

Crocuses—especially yellow ones—should be protected from sparrows with black cotton stretched between sticks. All bulbs, except Tulips, are better left in the ground from year to year. Where bulbs *are* lifted and replanted annually (as is necessary when they are grown in boxes, tubs, etc.) they should be able to finish their leaf-growth in a nursery. They should then be stored for the summer in some cool, dry, and *mouseproof* place. Mice adore Tulips and Crocuses, so these succulent corms are safest in paper bags suspended by string from the roof of a tool-shed or attic.

Planting a Plant

Children will often do planting during the Gardening course, so they should be able to practise early in their first term on something unimportant. It is a good plan first to plant Foxgloves in a shrubbery, as they stand clumsy handling well.

The ground should have been dug recently, but not too recently, and be neither sticky nor very dry.

The hole made should be wide enough for all the roots to be spread out sideways to their fullest extent: any damaged ones should be cut off just above the wound with a sharp knife. A trowel should be used for small plants (never a dibber) and a spade for large ones. Friable soil should be worked in amongst the roots by hand, and the plant waggled up and down frequently to settle the soil. Then it should be trodden round or else "firmed in" with the handle of the trowel. When finished, the crown of a herbaceous plant should be just above the surface of the soil. Children tend to plant much too loosely or else to bury the plant too deeply, and so need much practice under supervision.

Digging

(*a*) WHY?

The word "manure" is derived from an old French word meaning "to work with the hand." It would be better to dig the soil and not manure it at all than to add the costliest fertilizers but not dig.

All cultivation—whether ploughing, harrowing, digging, trenching, or hoeing—*aerates* the soil, and this aeration is the basis of fertility.

Children should know that they dig to let air into the soil in order that the roots of plants may breathe, and also the beneficial bacteria—the tiny soil-cooks or soil-chemists—that *prepare* the food in the soil for the plants to assimilate.

They dig so that they can improve "bad" soils by adding to them what they need—leaf-mould to a light soil, sand to a heavy one, etc.

In digging, injurious ground-pests are turned up so that birds see and eat them, and weed-seeds and small weeds are buried so deeply that they die.

They dig so that rain can percolate easily and frost penetrate deeply into the soil and improve it by "weathering." At this point in the course a medicine-bottle may usefully be filled with water, corked, and left out at night during severe frost. The ice-bottle and shattered glass will teach how frost "improves" lumps of clay—why digging should be done early in winter—better than many words.

(*b*) HOW

Digging is a question of knack, and need not be "heavy" work if the body is used intelligently. Most of the work should be done with the ankle, the wrist, and the shoulder: there need be no heaving and pushing with the abdominal muscles.

The spade should be driven in entirely with the ankle, and the lifting and throwing be done with the arms.

In clay soils, a fork should be used for much of the work instead of a spade.

Children should not try to lift much soil upon the spade. It is a good plan for little girls to dig standing at right angles to their main trench instead of parallel to it. Very thin slices of soil along the *width* of the trench can then be turned over, and risk of over-fatigue is avoided. Girls should not wheel heavy barrow-loads: small wheelbarrows should be used and only partially filled with soil—which should be piled towards the front over the wheels, not near the handles. A small trek-cart, such as Boy Scouts use, is better than barrows for the shifting of soil, because several people push and pull it: it can be made by Handwork pupils if wheels and wood are requisitioned.

The barrowing of soil, the carrying of water, and the mowing and rolling of grass are the only gardening operations likely to strain girls if not carefully supervised. If *common-sense* methods are employed and the children watched, girls can safely do all that the boys do. It should be considered "bad form" to exhaust oneself in the garden.

(*c*) METHOD OF SIMPLE DIGGING

To dig a plot one spit (foot) deep, a trench should be made across one end of it 15 in. wide and 1 ft. deep. The soil from it should be conveyed, in barrows or trek-cart, to the other end of the plot, and left there ready to fill the last trench.

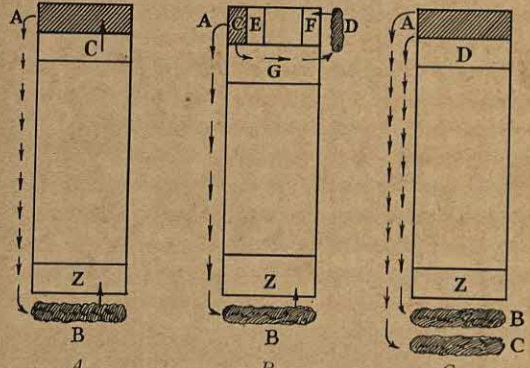
The finished trench should look like an oblong box, with no loose "crumbs" of soil in it. Then a space 1 ft. wide should be marked off next to it, and the soil from this dug into the empty box. Care should be taken to turn the soil topsy-turvey when throwing, and to throw as evenly as possible. Finally, all the "crumbs" should be scooped out of the second trench so that it, too, looks like a box when finished. A third 1 ft. wide strip is then marked out and dug, and the procedure is repeated until the end of the plot is reached and the soil that came from the first trench goes into the last one.

The reason that the first trench is made 15 in. wide and the others only 1 ft. is that children and other beginners invariably "dig high," and to allow for this error the first trench should be a little too big. For experienced diggers all the trenches should be the same size.

(*d*) MANURING

In order that a simple rotation can be practised, a portion of each plot should be manured each winter. If manure cannot be afforded, leaf-mould or other humus should be used instead. It should be laid along the bottom of the empty trenches and the soil dug in on the top of it.

The portion *not* manured should have powdered chalk or limestone sprinkled thickly over the *surface* of the soil after each trench has been filled.



A
Simple Digging

B
Double Digging

C
Full Trenching

FIG. 6

A. SIMPLE DIGGING. *Remove soil from Trench A and wheel to Pile B. Dig soil from C into A and so on along strip to end—when Pile B goes into Trench Z.*

B. DOUBLE DIGGING. *Remove top soil from Trench A and wheel to Pile B. Then remove bottom soil from little Trench C and wheel to little Pile D. Dig from Trench E into Trench C until end of little Strip is reached and Pile D goes into Trench F. Dig top soil from big Trench G into big Trench A and dig along bottom of big Trench G as A was done. Continue to end of strip—when Pile B goes into Trench Z.*

C. FULL TRENCHING. *This is a* BAD *method of deep cultivation. The top soil from A is wheeled to B. The bottom soil from A is then wheeled to C. The top soil from D is then thrown into the bottom of A, then the bottom of D goes on top in A—thereby reversing position of layers of soil and bringing infertile subsoil to surface. When end of strip is reached B goes into bottom of Z, then C on top of it.*

Quick-lime should on no account be slaked on school premises: it is highly dangerous. Calcium carbonate is the safe form of "lime" for children's use.

"LIME"

Soils tend to become acid or sour, with the sourness of lemon-juice or vinegar. This condition is injurious to the growth of most plants and also to the beneficial bacteria in the soil, and it prevents manures and fertilizers from parting with their locked-up plant-food. Some form of "lime" counteracts this harmful acidity.

Calcium oxide, or quick-lime; calcium hydroxide, or slaked lime; and calcium carbonate, which is chalk and limestone; all are covered by the gardener's loose term "lime."

Beside correcting acidity, "lime" is a key which unlocks plant food already in the soil and in various manures and fertilizers, but not in a form which can be assimilated by roots.

In many cases, however, it should not be applied with other fertilizers, as the resulting chemical reaction will be so quick that plant food will be wasted. It should not, for instance, be applied at the same time as stable or farmyard manure. "Lime" is, in itself, a valuable plant food.

Then it has a most valuable physical effect on "bad" soils. It helps to bind together a light soil and it breaks down heavy clay by a process called flocculation. It also discourages soil pests and plant diseases. It is the most valuable of all fertilizers, and amongst the cheapest of them.

It should be applied *early* in the winter, and, as it is heavy naturally, it should be scattered on the surface of the soil—not dug in—at the rate of ½ lb., or more, per square yard (4 oz. per square yard only if the corrosive forms are used). Chalk can go on at the rate of 1 lb. to 2 lb. per square yard. in a market-garden, but, in the interests of economy, the smaller dressing is recommended for schools.

Rhododendrons, Azaleas, many Heathers, and some Lilies and Primulas dislike "lime" intensely: it is frequently applied to shrubberies where Rhododendrons are—with disastrous results.

II. The First Spring Term

During the first Spring, frequent inspections should be made, as there will be much to observe and discuss. Bulbs and early border plants will be coming out; tree buds bursting; centipedes, millipedes, wire-worms, etc., will be turned up during digging and should be discussed as they arrive. Birds will become very tame now if regularly fed.

Now is the time for the life histories of many creatures to be begun, and particular stress should be laid on the *good* that many of them do to the garden. A list of garden-friends should be compiled, including soil bacteria, centipedes, earth-worms, ear-shelled slugs, ladybirds, ichneumon flies, hover and lacewing flies, all the insect-eating birds—with hedgehogs, toads and frogs—and as much learnt about them as possible.

Now is the time for simple lessons on soils—how the soil was formed; what constitutes a "bad" soil and why? methods of improving soils—and also for talks on the weather.

The chief work of the term will be the planning and sowing of the seed-plots.

Arrangement of the Plots

Each seed-plot should contain a leaf-crop, a pulse crop, a root-crop, and some flowers, but they need not all be cropped alike.

Room should be allowed for experiments and a nursery *in each plot*, UNLESS the children can have the use of other ground set aside for this purpose.

An ideal first-year arrangement would be to sow Broad Beans, with Spinach as an intercrop; then Onions; and then Cabbage Lettuce on the manured section of the plot—the Beans to be followed by Cabbage plants, the Lettuce by Cauliflower or Early Broccoli. The unmanured section would have Radish, Early Shorthorn Carrot, Early Turnip, a space for nursery and experiments, and an edging of hardy annual flowers. The Carrots and Turnips would be followed by pricked-out biennial flowers, and in the space for nursery-work would be sown the Brassicas for later transplanting—Cabbage in one plot, Cauliflower in another—and the biennial flowers.

A small trodden-down path should divide the manured from the unmanured section, and each section should be planned so that it begins with that crop which should normally be sown first. Crops which are sown very early, as Parsnips and Broad Beans, are not suitable for the middles of their sections: they should *begin* them. When workers are children and plots small, everything possible should be done to avoid unnecessary trampling (see Fig. 7A).

Plans of the plots should be drawn to scale in the garden diaries of the children before a seed is sown.

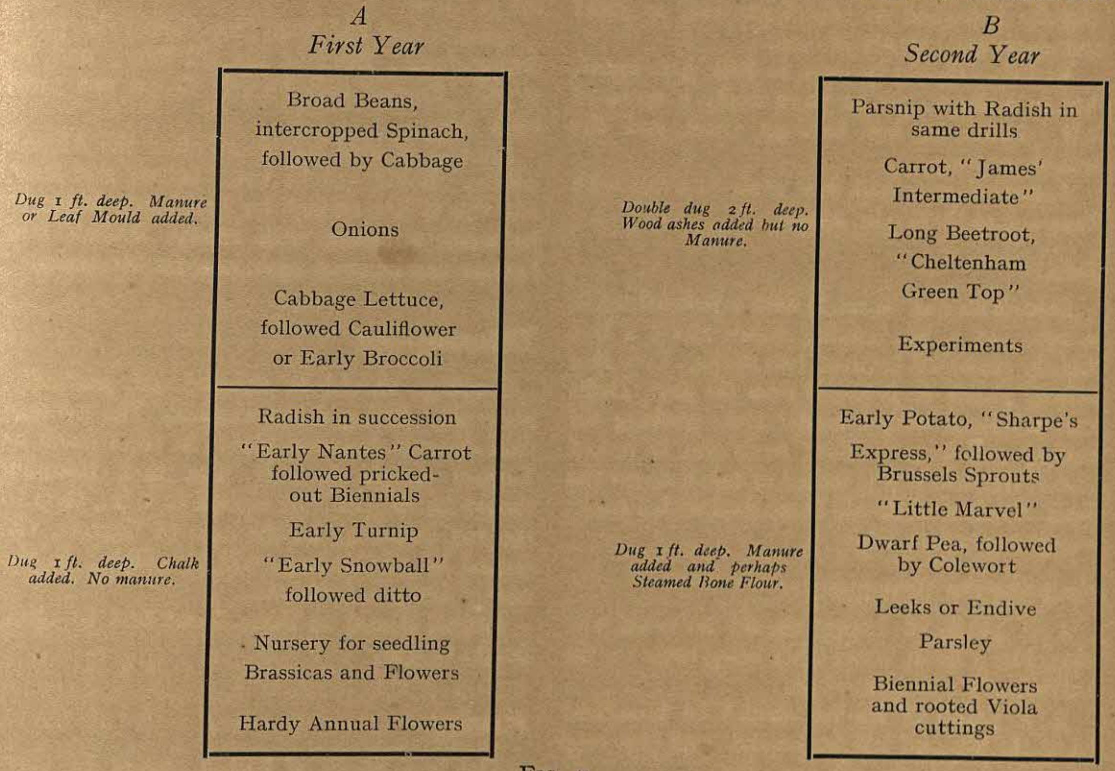

A
First Year
Dug 1 ft. deep. Manure or Leaf Mould added.
Broad Beans, intercropped Spinach, followed by Cabbage
Onions
Cabbage Lettuce, followed Cauliflower or Early Broccoli
Dug 1 ft. deep. Chalk added. No manure.
Radish in succession
"Early Nantes" Carrot followed pricked-out Biennials
Early Turnip
"Early Snowball" followed ditto
Nursery for seedling Brassicas and Flowers
Hardy Annual Flowers
B
Second Year
Double dug 2 ft. deep. Wood ashes added but no Manure.
Parsnip with Radish in same drills
Carrot, "James' Intermediate"
Long Beetroot, "Cheltenham Green Top"
Experiments
Dug 1 ft. deep. Manure added and perhaps Steamed Bone Flour.
Early Potato, "Sharpe's Express," followed by Brussels Sprouts
"Little Marvel"
Dwarf Pea, followed by Colewort
Leeks or Endive
Parsley
Biennial Flowers and rooted Viola cuttings

FIG. 7

Arrangement of Seed Plots

Seed-Sowing

Spring-Term seed-sowing begins with Parsnips, Broad Beans, and Round Spinach in late February or early March; continues with Dwarf Early Peas, Onions, Radish, and Lettuce in mid-March; ends with Early Carrots and Hardy Annual Flowers towards the end of March. Brassicas (e.g. the Cabbage-tribe) also should be sown during March in the nursery or in boxes.

If weather conditions are unfavourable, the operation should be deferred. Seeds should *never* be sown when the land is wet or frosty nor upon a windy day.

Seeds should not be sown within a fortnight of the digging of the seed-bed. Just before a row is sown, the surface of the soil should be knocked down into a fine tilth and pulled as level as possible. A border fork can do everything that a rake does, and, in inexperienced hands, it does it much better. Unskilful raking may easily produce a pasty crust on the top of the soil, striped with ridges of stones and lumps.

The Onion-bed, and, *in exceptionally light soils*, all the seed-bed, should be trodden firm before seeds are sown; and the children should try to find out why an infant Onion, or other Monocotyledon, needs a firm bed and an infant Parsnip does not. Why, for instance, is a newly-sown lawn rolled with a roller but not a newly-sown Bean-bed?

DEPTH AND DISTANCES

The depth to sow seeds is a common-sense matter: the larger they are, the deeper down they go. (Why?) Broad Beans can go 3 in.

deep, Peas 2 in., Nasturtiums and Lupins 1 in., the majority of small seeds such as Lettuce, Turnip, etc., ½ in.; and tiny ones like Shirley Poppy should be mixed with twice their bulk of sand and sprinkled on the top of well-firmed soil.

The distance between rows should be not less than the height of the mature plant. Thus, Broad Beans need at least 2 ft.; "Little Marvel" Pea 18 in.; Carrots and Turnips 1 ft.

If space allows, these distances should be slightly increased in school gardens, as child gardeners need plenty of room.

Radishes should be sown in drills 3 in. apart, but in order to get at them easily a space of 1 ft. should be left between them and the neighbour crop.

Annual flowers look best sown in ovals with lines across them 9 in. apart.

DRILLS

Seed-drills can be made with a pointed stick, a ruler, or a hoe-handle, drawn along a line tightly stretched between two sticks. *Very thin sowing should be practised from the first.* Drills can be closed with a border fork, working the tool *up and down* the line: seeds may be jerked out of the drill if it is forked or raked *across* the line. Every drill should be marked with a stick; every crop with a label.

SEED-SOWING EXPERIMENTS

1. A patch of Poppy should be sown 3 in. deep like a Bean, some other being sown on the surface of the soil elsewhere.
2. A patch of Radish should be broadcast very thickly and left unthinned, and this crop compared with the ordinary crop.
3. A few Radish, Carrot, Turnip, and Cabbage seeds should be sown where they can flower and seed, and their whole natural life-cycle be observed.
4. A few Carrots might be sown over a thinly-covered spadeful of fresh stable manure, and their growth compared with that of the ordinary crop.

ENEMIES

Sparrows see tiny Lettuces before we do and cats maraud before the seeds are up. The best method of coping with both is to stick a number of small pointed sticks on each side of each drill and wind black cotton amongst them. A dusting of soot discourages slugs, and this might be given by the *teacher*: the first time the children are allowed to sow soot will also be the last time!

III. The First Summer Term

Early Turnips should not be sown until April, and then only in showery weather or they are apt to "bolt."

Spinach-beet and Main Crop Carrot also go in during April; Beetroot not till May; and, *in schools*, Runner and French Beans not until early June.

Annuals wanted for bloom after the August holiday should not be sown before mid-May, and this is late enough for half-hardy kinds to be sown outdoors with safety. Radish and Lettuce can be sown again now for succession.

Thinning-out

Seedlings should be thinned out *gradually*, preferably during damp weather. The average final distance between plants in rows (such as Turnip) should be 1 ft. The first thinning should be to 3 in., the second to 6 in., then to the full distance. In the case of Carrots, the second lot of thinnings will be edible; in the case of Lettuce, both lots.

Radish should be thinned out first to 1½ in., finally to 3 in.

Hoeing

The importance of hoeing cannot be overemphasized (see right-hand headpiece). If the Dutch hoe is regularly used between rows of seedlings and between border plants, few weeds will be able to grow, and the soil near the roots of the plants will be constantly aerated. Also, soil-moisture will be conserved so that little watering need be done. In unhoed soil, rain-water is quickly drawn up to the surface by capillary attraction, and there it evaporates.

But this ascending water cannot jump across the big air-spaces between the lumps of hoed soil, and so the column is broken and the water remains in the ground. (Capillary attraction is most quickly demonstrated to children by putting a tall block of common salt in a saucer of red ink.)

A child should use a Dutch hoe by walking backward as he pushes it about in front of him.

FIG. 8

A Weeding Party

Watering

Watering is usually overdone and almost always badly done. Water should be given *copiously* and regularly or else not at all. Young seedlings need it in dry weather; Lettuces always twice a week except when it rains; newly planted-out plants until they are established.

Shrubberies, herbaceous borders, Potatoes, and long-rooted plants do NOT need watering except during severe drought.

Whenever watering is done, *enough should be given to soak right in:* frequent damping of the top inch of soil is extremely harmful, as roots are attracted by it to the surface of the soil, where they are dried and scorched.

Water should, if possible, be given from a sun-warmed tub—not straight from a cold tap.

Weeding

If the Dutch hoe is used regularly, the only weeds on the plots will be those in the lines of seedlings. These should be removed whilst small with a hand-fork in damp weather, and the soil pressed back afterwards so that the roots of the crop are not exposed.

Large weeds on neglected ground should be dug out with a border fork and burnt—*not* buried in the compost-heap. Old dinner-knives get up Plantains in lawns as well as anything, and children should discover *why* the rosettes of Plantains, Daisies, and Dandelions abound in mown grass, yet Chickweed and Groundsel do not.

Weeds on roads and paths should be chopped off with a draw-hoe.

Shepherd's Purse is so useful as botanical material that some should be carefully moved to the nursery, where it can be cherished until wanted.

Pricking-out and Transplanting

Young plants need gentler handling than old ones. They should be planted firmly enough not to be easily tweaked out of the soil, but the necessary pressure should come from the planter's thumbs, not heels. When possible, this work should be done soon after rain on a grey day.

FIG. 9

Staking

"as gracefully and naturally as possible, and before the plant actually needs it."

Unfortunately it very often *has* to be done in dry and sunny weather, as it is towards the end of the summer term that young Cabbages, etc., have to go into the site of early crops now harvested. The difficulty should be met by "puddling-in" the young plants: that is, by pouring water into the bottom of each hole and letting it soak in just before the plant is planted. During the heat of the day, newly-planted Cabbages, etc., should have overturned flower-pots (to fit them) put one over each. One or two plants should be left without flower-pots, compared with the others, and a reason found for the difference observed.

Staking

A worn-out besom provides excellent twiggy stakes for Dwarf Peas. Broad Beans can be kept erect by a string each side of them strained to sticks at the ends of the row. Suckers or prunings from shrubs can be used for the taller annuals and perennials, or bamboo-canes bought (these last much longer than other plant-stakes).

Sweet Peas need tall, twiggy boughs. All staking should be done as gracefully and naturally as possible, and *before* the plant actually needs it.

Harvest

In the first Summer Term, Radishes, Lettuces, Early Carrots, and Turnips, Broad Beans and Early Peas will be ready to eat approximately about the end of June (July in the North), and March-sown Annuals will be in bloom in June and July.

Children should be drawing, in their garden diaries, some of their crops at different stages of growth. It is important that a Radish, Carrot, or Turnip should be sketched whole—as it appears when ready for eating—and this drawing compared with a later one made of a specimen of the same crop when it is *flowering* in the experimental-plot. The root of a *flowering* Carrot should be noticed particularly.

SECOND YEAR'S WORK

I. The Second Autumn Term

Biennial and perennial flowers sown in summer and then pricked out in the seed-plots should, this term, be planted out in their permanent quarters—about a foot apart for Wallflowers and Foxgloves, more for tall perennials.

When a herbaceous border is being planted, as much as 3 ft. should be allowed between big back-row plants such as Michaelmas Daisies, and 2 ft. or 18 in. between perennial Poppies, etc.

Even small edging plants like London Pride need at least 9 in. between them. The big spaces in newly planted borders can be temporarily filled with Annuals.

Herbaceous Cuttings

Herbaceous cuttings can be made in September and October from Violas, Snapdragons, Shrubby Calceolarias, and Catmint. For schools, the Viola is best of all.

They need the protection of glass in winter, and Handwork pupils can cheaply make a small cold frame: even a sheet of glass laid across a tub or sugar-box will do.

The compost should be well-drained and top-dressed with an inch of sand.

Shoots selected for cuttings should be from healthy plants. They should be vigorous, short-jointed ones, with solid stems bearing neither buds nor seed-pods.

A Viola cutting should be about 3 in. long (Snapdragons 4 in.), and the cut should be made immediately below a node with a very sharp knife. *Before* they begin this work, children should protect the ball of the right thumb with sticking-plaster or a glove-thumb.

All leaves and bracts should be removed except three leaves at the top. Holes should be made about 2 in. deep and 3 in. apart with the finger, the *flat* end of a pencil, or a *blunt* stick, and a little of the sand pushed into them. The cuttings should stand upon the flat bottoms of the holes, and be "firmed in" so that they cannot easily be tweaked out.

There should be discussion as to why sand helps roots to form quickly, why roots come from a buried node, why some leaves are cut off, why shoots with dead flower-heads on them should not be chosen for cuttings. Glass should be kept over the cuttings in frosty weather, but air given on fine days. They should be "hardened off" well before being planted out in April.

Shrubby Cuttings

In November, cuttings of Rambler Roses, Gooseberries, and Black and Red Currants may be made and rooted out in the garden.

Straight pieces of young wood should be selected about 15 in. long, and a straight cut be made just above a node at the top and just below one at the bottom. All the buds but the top three should be nicked out of the Red Currant cutting, because it fruits on old wood, so young suckers from the bottom are not wanted. It is more convenient, too, for a Gooseberry bush not to have growths from the bottom—though it fruits on all its wood.

But Black Currants and Ramblers bear upon *young* wood, so new growths from the ground *are* wanted: all buds should therefore be left upon these cuttings.

A triangular trench should be made in the nursery by driving a spade into the ground, then waggling it backward and forward. Some sand should be sprinkled in and the shrubby cuttings arranged so that they stand 6 in. apart and are buried 6 in. deep. The trench should then be closed by treading. In one year the rooted cuttings will be ready to transplant to their permanent quarters.

Reasons for the differences between the methods of propagating a shrub and a herb should be discussed.

Pruning of Ramblers, Raspberries, etc.

Pruning is done to admit light to all parts of the tree or bush, to enable air to circulate freely amongst the leaves, to check the spread of pests and diseases, to enable fruit or flowers to be easily picked, to make the tree a desirable shape, and to direct the strength of the tree into bearing wood. In some plants, fruit and flowers are borne upon the young wood; in others upon the old wood: in pruning, therefore, it is most important to remove the *non*-fruiting growth.

Rambler Roses, Raspberries, Blackberries, Black Currants, and Morello Cherries all fruit on the young wood, so the pruning of them consists of thinning out, not shortening.

Although pruning can be done any time whilst the sap is down, it is sensible to do some of it in late October or early November, as then portions of Currant and Rambler prunings can be turned into cuttings.

If there is sufficient young wood growing up from the ground, the *whole* of the old growth of Ramblers, Raspberries, Loganberries, and Blackberries should be cut out from the bottom. Sharp *sécateurs* may be used for this kind of pruning; sharp knives for all shortening of wood.

In the case of some Ramblers it is necessary to leave one or two old growths: those with most young side-shoots on them should be selected. Black Currants are less simple to manage. Every year that of the old wood should be cut out which bears the fewest young shoots upon it. Some old wood always has to be left, for the sake of the young growth upon it. It is from the young lateral shoots from old growths cut from Ramblers and Black Currants that cuttings are economically made.

Double Digging

That part of the seed-plot which was manured last year for leaf-crops should this year be dug 2 ft. deep instead of 1 ft., be given potash (in the form of bonfire ash) and humus, but no animal manure, and be used largely for long-rooted root crops.

A trench 2 ft. 3 in. wide (2 ft. for professional gardeners) and 1 ft. deep should be excavated, and the soil from it wheeled to the end of the *section*—NOT to the far end of the plot. When a box-like trench has been made, with no "crumbs" of loose soil left in it, some humus from the compost-heap made last autumn may be laid along the bottom of it. One child at a time should then get into the trench and dig the *bottom* of it 1 ft. deep, turning in the humus in the process. The digging should be done across the *width* of the trench, and from one end to the other. A border fork is better than a spade for stiff sub-soils.

The most thorough method is to remove 1 ft. of sub-soil from one end of the trench and dig into the hole as described for simple digging, replacing the excavated sub-soil at the other end of the trench.

When the bottom of the first big trench is dug over to the depth of 1 ft., soil from the strip next to it should be dug into it, and so on. All the strips except the first one should be 2 ft. wide. (See Fig. 6*B*.) Wood-ash should be sprinkled on the surface of the finished strips.

IMPORTANCE OF DEEP CULTIVATION

Land intended for herbaceous borders, fruit, roses, shrubs, and other permanent crops should be double-dug a few weeks before it is planted. Every part of the vegetable-plots should be double-dug periodically, so that the whole is so treated eventually.

Deep cultivation induces fertility as nothing else can.

OTHER METHODS OF DEEP CULTIVATION

Double-digging is more suitable for school gardens than the difficult form of deep cultivation known as bastard-trenching.

In both, the aim is to aerate and improve both layers of soil, but to keep the more infertile bottom layer at the bottom.

Full-trenching (see Fig. 6*C*) would reverse the positions of the two layers, bringing infertile sub-soil to the surface: the evil results of this method, in all but old, deeply-worked soils, should be discussed with the children.

Manures and Fertilizers

Most of the mineral substances required by plants (these might be named and discussed) are found in sufficient quantity in ordinary soils. But phosphates, potash, and nitrates are not, and should therefore be added periodically. A tripod will not stand with any one of its three legs missing, so this group of essential fertilizers is often referred to as "The Golden Tripod." Almost all plants need all three of them, but in varying quantities.

Plants grown for their leaves and stems (Grass, Cabbages, Leeks, etc.), including those with underground stems called tubers (Potato) and the bulb of an Onion, need abundance of nitrates, so should be given animal manure or sulphate of ammonia. Potash is liked by fruit, flower, and seed-crops, but specially by plants with large food-larders containing carbohydrates—Potatoes and Peas are starch-hoarders, Beetroot and Fruits sugar-hoarders, and Jerusalem Artichokes hoard inulin—so wood-ashes should be saved for them. Flowering corms and bulbs, too, store food, though human beings do not appreciate the carbo-hydrates in a crocus-corm as any mouse does.

Phosphates help the reproductive organs, so are needed by plants grown for flowers, fruits, or seeds.

The best and cheapest type of phosphatic manure for use on all types of soils is steamed bone-flour. Bone-meal is also good, but acts more slowly.

Horticultural terminology is loosely used, but the word "fertilizer" usually means an *incomplete* plant-food: the word "manure" means a *complete* plant-food—stable-manure, for instance, contains phosphates and potash as well as nitrates.

In a two-year course it is inadvisable to burden children's memories with details of the various types of different fertilizers commonly used on various kinds of soils. Schools cannot afford to use many of them, and a more than elementary knowledge of chemistry is needed to appreciate their reactions with each other and with the soil.

II. The Second Spring Term

The second portion of the seed-plot should be dug 1 ft. deep and manured, and might have a sprinkling of steamed bone-flour if this can be afforded.

Early in the term, seed Potatoes should be put to sprout in a light, frost-proof place. The rolling and raking of grass should be noticed.

Arrangement of the Plots—Second Year

The portion of the seed-plot dug 2 ft. deep might have Parsnips first sown upon it (Radish may be sown actually in the same drills with it), then Intermediate Carrots, then Long Beet, and then there should be a space of experimental work.

The manured portion might start with Early Potatoes to be followed by Brussels Sprouts, then "Little Marvel" Pea to be followed by Colewort, then Leeks or Endive, edged with a border of Parsley (Radish in the same drills) or flowers—the Viola cuttings made in autumn could be planted here with biennials raised last summer. (See Fig. *7B*.)

Peas are sown in a special way: a 6 in. wide drill should, with a draw-hoe, be scooped out 2 in. deep, and the Pea seeds sown in it 2 in. apart. The soil can be gently drawn back over them with hoe or fork.

Pruning

PRUNING OF APPLES AND OTHER FRUIT

Apples, Pears, Plums, all Cherries but Morellos, and Red Currants fruit on old wood, so the pruning of them consists largely of shortening new wood to little spurs.

First the shape of the tree has to be considered, and the "leaders," which are to continue existing branches or form new ones, should be shortened so that 1 ft. of new wood is left. The cut on a "leader" should always be made above a *wood*-bud (not a fat fruit-bud) and one which points *outward*. Then young lateral shoots should be cut back so that a little spur of 2 in. or 3 in. is left, on which fruit will be formed. This cut may be above a fat fruit-bud.

Gooseberries fruit on old *and* new wood, so can be pruned partly by thinning-out and partly by shortening.

A very sharp pruning-knife should be used for all shortening, as *sécateurs* are apt to bruise wood and cause "dying-back" below the cut.

Children should be taught to use a pruning-knife sensibly. The branch should be firmly held with the left hand just below the place to be cut, the cut made just above a bud, with the knife slanting *away* from the operator. To cut oneself pruning should be considered disgraceful—the hallmark of clumsiness and carelessness—a thing "not done"!

The pruning of all fruit should be finished before 14th February when buds begin to burst.

One Gooseberry bush should be left unpruned from year to year, the fruit from it compared with the crop grown from a pruned bush, and its general condition studied.

ROSE PRUNING

Bush Roses are a law unto themselves. The more delicate Tea Roses should not be pruned until 1st April, other kinds may be started on 25th March. The weaker the Rose, the harder it should be cut, and it is better to prune too hard than not hard enough. A good rule is to cut back leaving only three to five buds on each branch, and always to cut just above a bud which points *outward*. Very strong varieties, such as *Rosa rugosa*, the Penzance, and all other Sweet Briars, and the little Polyantha Roses (tremendously vigorous for their size) should not be pruned at all except for the removal of dead or weakly wood or for occasional thinning-out if branches are over-crowded.

Potato Planting

Early Potatoes should be planted in March, when the soil is in a friable state. The rows should be 2 ft. apart and the tubers 1 ft. apart. They can be planted singly, with a trowel as bulbs are, in holes 5 in. deep; but the best method is to mark a straight line and then dig a 5 in. trench along it with a spade. Wood-ashes may be sprinkled along it and then the tubers placed in it, sprouts upward, 1 ft. apart. The ridge of soil should then be drawn over them with a draw-hoe.

III. The Second Summer Term

In early May, Beet and Endive may be sown. The Beet "seeds" should be sown singly.

When several seedlings emerge from one "seed" it should be dug up and examined. A single Pea or Turnip seed does not behave so, and an explanation should be sought.

Rooted Viola cuttings will be ready to plant out in April and early May.

When Pea plants are dug up, the nodules on the roots of them should be pointed out and discussed.

A young Loganberry or Blackberry shoot may be pegged down in loosened soil to root from the stem; and, towards the end of the term, Strawberry runners may be pegged down into buried pots of soil and kept watered.

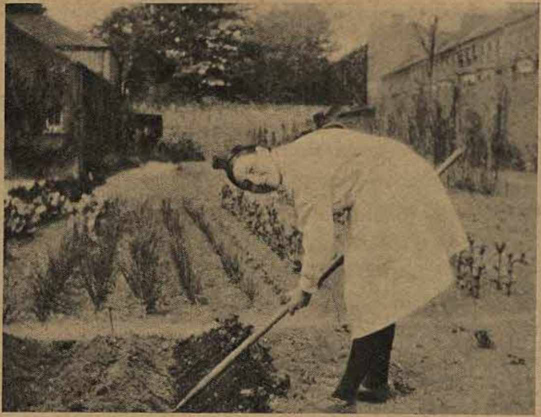


FIG. 10
Earthing-up Potatoes

Layering and budding might be attempted in June, but are better deferred.

Earthing-up and Lifting of Early Potatoes

Potatoes should be earthed up twice—once when they first appear, once later—using a draw-hoe.

The ground should be chopped at least 10 in. away from the plant to avoid injury to the roots and drawn up into two ridges, one each side of the leaves. There should be a dip between the two ridges to catch rain.

Earthing-up protects the delicate foliage from late frosts, provides a soft, airy medium for the tubers to form in, keeps light away from the tubers, and, to some extent, checks the spread of disease.

One plant should not be earthed-up at all—for comparison. Another should have an overturned wooden box put over it for most of every day, and the crop from it should be both weighed and tested for starch, the results being compared with the weight and the starch-content of the tubers from a plant exposed always to sunshine.

When lifting Potatoes, take care not to drive the fork in too close to the plant, or the tubers will be impaled. The excavated plant should be carefully examined before all the tubers are knocked off and the children shown how tubers differ from roots.

Blanching

Young Leeks, sown in early spring in the nursery, should be planted out in holes 10 in. deep—which *may* be made with a dibber. One Leek should be dropped into each hole and then the holes filled with water. This will wash down enough soil to cover the roots. Subsequent waterings and rain will gradually fill up the holes so that the Leeks are blanched.

One or two should be planted on the surface of the soil and compared later with the blanched ones.

Endive can be blanched by placing an overturned flower-pot (with hole stopped up) over each plant: a few should be left unblanched, for comparison.

SCHOOL GARDENS ON DIFFICULT SITES

Lack of Space

No school should be without a garden. Where there is a flat roof, or a portion of asphalt playground can be spared for the purpose, a garden can be made entirely out of deep boxes and tubs—a garden which will provide work and crops continually for six consecutive school terms. If there is no available space outside, much can be done with several window-boxes. If there are no window-ledges, still much can be done inside the classroom with pot-plants, bulbs in bowls of fibre, miniature gardens, etc.

There are two important points to keep in mind when making an educational garden in boxes or window-boxes—

1. There should *always* be one, or more, "nursery" boxes apart from the "show" boxes —some place where lifted bulbs can grow naturally until their leaves are dead, seeds be started for planting out, and cuttings be struck. Such a nursery can usefully be put at the shady end of a roof garden or in a shady window-box.

2. The receptacles should never be less than 10 in. deep: 1 ft. is better. Apple-boxes are the cheapest suitable type to be had: they are stronger and deeper than grocery boxes. Half butter-tubs will do, and also half oil-casks. All receptacles should have drainage-holes made in the bottoms of them and plenty of rough stuff (potsherds, etc.) be placed over the holes below the compost. Further, to facilitate drainage, all boxes should stand on two pieces of tile or else have two strips of wood nailed underneath them to raise them clear of the ground.

A Roof Garden

A useful roof garden might consist of six or eight apple-boxes for early bulbs and seeds, two tubs for later crops, two for nurseries, and two for water.

In the first year the boxes might have Scillas, Crocuses, Chionodoxa, Snowdrops, Aconites and Golden Spur Daffodil in them, followed in Spring by Virginian Stock, Nemophila, Candytuft, Radish, "Tom Thumb" Dwarf Lettuce, and Spring Onions. (The bulbs would go to the nursery tub directly after flowering, to make room for the seeds.) The late tubs might have May-flowering Tulips or Daffodil "Grandis," followed by Tomato or Marrow plants bought from a market in June.

In one nursery tub, Wallflower, Myosotis, or Button Daisy might be sown in May after the earliest bulbs had finished their life-cycle.

The second one might, with glass over it, be used to strike Viola cuttings in Autumn after the later bulbs were quite over.

Thus in the second year there would be enough home-grown Wallflowers, Violas, etc., to crop the six apple-boxes with, and space in the late tubs and nursery tubs for experiments and new work. Pink or Carnation "pipings" might, for instance, be made during the second summer.

This scheme could be modified to suit window-boxes.

Shady and Smoky Gardens

For a very shady garden all bulbs but Tulips are suitable, and any of the plants quoted for Shady Borders—see Group B, p. 182. Few vegetables will grow, but Turnips might be tried, and Rhubarb, Parsley, and Land Cress will flourish.

The most suitable fruits are Black Currant, Raspberry, Gooseberry, Damson, and Bullace. A north wall might have a Victoria Plum or Morello Cherry on it—though the fruit might ripen in the August holiday. Both are self-fertile.

Roses, "Gloire de Dijon" and "Reine Marie Henriette," will do on a shady wall, and so will Winter or Summer Jasmine.

The most likely annual is Convolvulus: the best biennials, Evening Primrose and Foxglove.

For a shady rockery see Group P, p. 183.

A few plants will flourish even on the *worst* of soils and in the densest shade. They are Garden Bluebell (*Scilla Hispanica*), Star-of-Bethlehem, Irises, Solomon Seal, *Dielytra*, Male Fern, London Pride, Creeping Jenny, Foxglove, and Evening Primrose.

Where the atmosphere is smoky, all plants with hairy or woolly leaves should be avoided—such as Violets, *Stachys*, etc., also most Alpines, most Winter Greens, and all Evergreen Shrubs.

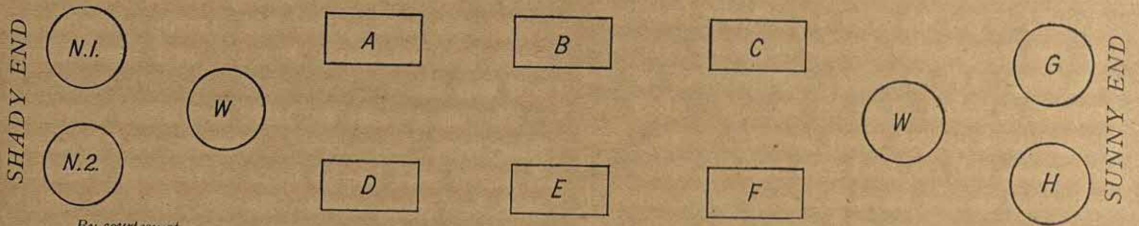
Steep Banks

Broom and Gorse will do well on the steepest sunny banks, but should be put there as seedlings in damp weather or else sown straight there and thinned out later. *Rosa rugosa*, Sweet Briar, *Rosa spinossissima*, and any kind of Rambler or *Wichuriana* Rose will succeed: this last should be planted near the top and allowed to romp downward. Of fruits, Loganberries and Blackberries may be allowed to run downward—not be tied to stakes—and Alpine Strawberries will flourish. A fine decorative effect can easily be got on a large bank by planting irregular drifts of drought-loving flowering-plants of smothering habit. From five to nine plants of one variety should be planted together to get a bold group. For suitable kinds see Groups O and P, p. 183.

As it is impossible to water on a steep bank, plants should be put in immediately after rain, and the smaller they are the better.

Weeding should be done very regularly and carefully indeed at first, as once weeds get too large to remove easily with a hand-fork they are a serious problem on a steep bank. One reason why coarse plants of smothering habit are good on banks is that, once they are mature, they choke out most weeds.

PLAN OF A ROOF GARDEN



By courtesy of *The Journal of Education*

FIG. 11

FIRST YEAR

Box A. *Winter Aconites and Snowdrops followed by Virginian Stocks.*
Box B. *Yellow Crocus followed by Calendula.*
Box C. *"Golden Spur" Daffodil and Scilla Sibirica followed by Candytuft.*
Box D. *"Golden Spur" Daffodil and Scilla Sibirica followed by Radish.*
Box E. *Purple Crocus followed by Dwarf Lettuce.*
Box F. *Winter Aconites and Snowdrops followed by Spring Onions.*
Tub G. *May-flowering Tulip, "Pride of Haarlem," followed by Vegetable Marrow.*
Tub H. *Late Daffodil, "Grandis," and Muscari, "Heavenly Blue," followed by Tomato.*
Tub N1. } *Nursery tubs for ripening off bulbs and starting perennial*
Tub N2. } *seedlings in summer such as Double Daisies and Myosotis.*
Tubs W. *Water.*

SECOND YEAR

Box A. *Daisies and Myosotis started last year in tubs N1 and N2.*
Box B. *Ditto.*
Box C. *Ditto.*
Box D. *Violas and Calceolarias from cuttings rooted this winter in tubs N1 and N2.*
Box E. *Ditto.*
Box F. *Ditto.*
Tub G. *Experiments.*
Tub H. *Ditto.*
Tub N1. } *Viola and Calceolaria cuttings autumn to spring with glass over tubs.*
Tub N2. } *Pink or Carnation cuttings in summer.*
Tubs W. *Water.*

INTERESTING FACTS ABOUT ANIMALS

CASUAL observation of the forms and actions of common animals may be made the occasion of useful teaching. The more familiar the animal, the more effective is a lesson which throws new light on that which hitherto has been so ordinary as to be supposed not to stand in need of explanation.

Take, for example, the cat and dog. Every boy and girl will at once perceive the truth of the statement that cats and dogs are related: more nearly related, say, than cats and horses. Cats and dogs are both essentially carnivorous (flesh-eating) animals. Why, then, are cats and dogs so different? Why has a dog a long pointed face, and a cat a short flat one? Why is a cat so clean, and a dog not so clean? Why is a dog so sociable, and a cat not so sociable?

Dogs have Long Faces

To answer these questions we must first, so to speak, view our dogs and cats in their proper settings. Recollect that domestic dogs are descended from wild dogs (chiefly the creatures known as wolves and jackals). Now, it is characteristic of wild dogs in general that they hunt by running down their prey, tracking it mainly by scent. (Most pupils will have heard or read exciting stories about people being chased by packs of wolves.) It is plain that, for such a mode of hunting, a long face, with long jaws and good long rows of powerful teeth, is best. It enables the dog to reach well forward to snap at, and seize, the legs or throat of a retreating victim.

Cats have Short Faces

Domestic cats are descended from wild cats (chiefly the kind of cat which is variously called the African, Egyptian, or Caffre cat, and named scientifically *Felis caffra*). It is characteristic of wild cats in general that they hunt by stealth, by watching and waiting, the prey being finally secured with the claws at a bound. For such a mode of hunting all that a cat really needs are short jaws holding just enough powerful teeth to cut up the flesh of the prey. Moreover, the short face of the cat allows of the two eyes being set close together, right in the front of the face, where they can act with one another to give stereoscopic vision. The possession of stereoscopic vision means that an animal can *judge depth and distance,* and thus the cat is able to hit the mark when the fatal spring is made at the quick-moving prey. A wild cat which misjudged its distance, and consequently slightly missed stroke, would get few dinners.

Thus, a casual fact (that the faces of related cats and dogs are so different), known to everybody but rarely considered, is found to have a meaning: to have implications hitherto unsuspected.

Clean Cats and Unclean Dogs

Again, everybody knows that a cat washes itself and that a dog does not. Why is this? A wild cat must be so scrupulously clean that no odour can pass from its body to the keen nose of the prey. A dirty cat would be a hungry cat, for prey would be aware of its presence, and stalking would be almost useless. But it is really not a very important matter if an odour passes from a wild dog to the prey which it is chasing. Nay, unclean habits probably are of advantage, because the members of a pack of dogs can, by smell, follow in one another's tracks, and combine at the end of a long chase to attack the victim. The prey is often of large size (think, for instance, of a deer chased by wolves), and the larger the number of dogs which are "in at the kill" the easier will be their work, for the prey, worried on all sides, quickly succumbs.

Here, then, is the explanation of certain familiar traits of our tame cats and dogs. Cleanliness is essential to wild cats; it is so ingrained that it influences the behaviour of their domesticated descendants, even when those descendants are so pampered that they never even need to think of catching mice. Neglect of cleanliness is characteristic of wild dogs, and this ingrained character influences the behaviour of their tame descendants. A dog cannot be taught to wash, and a cat cannot be taught not to wash.

Sociable Dogs and Unsociable Cats

A dog makes a much better companion than a cat. (Do we not commonly say that dogs attach themselves to persons and cats to places?) Is there any unsuspected explanation of this fact? Wild dogs in general hunt in packs, and consequently are sociable animals. Domestic dogs inherit this trait. In its craving for the companionship of its master a tame dog is acting under the stimulus (sharpened no doubt by civilized life) of the ancestral instinct which operated to keep the pack together. Sociability is ingrained in the dog; it must have companionship; a dog without a friend is a dull dog. But wild cats in general are solitary hunters. Tame cats inherit the trait. Solitariness is ingrained in cats. A tame cat enjoys being cossetted, but it must be petted only when it likes, and usually it prefers to go its own way.

The Cat's Loose Skin

Everybody has been scratched by the sharp claws of a cat, and everybody knows that even a slight scratch is unpleasant. People often ask, when they see two cats rolling over and over and clawing at play, why the animals do not hurt one another. One explanation is that the claws are as a rule only unsheathed in anger. A second is that the fur of the one animal affords some protection against the claws of the other.

But there is a third reason. Have you ever lifted a cat by the skin of its neck? Have you ever seen a mother-cat take her kittens by this skin when she carries them from one place to another? A cat's skin is relatively loosely attached to its body. One could not easily take a man or a monkey by the skin of the neck, because the skin is more tightly attached. If a cat receives the claws of another at play, its skin "gives" somewhat, the points of the claws slip out, and little harm is done. If those claws had been in the relatively taut skin of a man they would have inflicted a scratch. A mother-monkey does not lift its young one by the skin; the young one clings with its arms to its mother. You will get bitten if you try to pick up a monkey as you would a cat. (And, by the way, if a cat gets its claws into your hand, do not snatch the hand away; you thus get a deeper scratch. Thrust your hand *further in*, and the cat's claws automatically slip out.)

The Wagging of the Cat's Tail

By remarks such as the foregoing the attention of the pupil is directed to the truth that there is interest in noting the commonest things, and he discovers that every seemingly isolated biological fact which he gets explained will throw light on some other facts yet unexplained, causes and effects being endlessly interlinked.

He may be asked if he has observed that a cat sometimes wags its tail. He may recollect (being prompted) that he has seen a mother-cat present the tip of her tail to her kittens, moving it to and fro, and tempting them to spring after it. The explanation of this is fairly easy: the mother is teaching her little ones the game of playing at life, that is, playing at catching prey. But a cat has also a peculiar way of quivering its tail when it is deeply intent on stalking a mouse. The explanation of this is not so easy. It has been thought that the action is a means of getting rid of nervous strain, of overmuch nervous excitement. When excitement reaches a certain pitch it discharges itself in tail-movement: an action perhaps analogous with the nervous tapping of a man's foot when he feels annoyance which he must not show but which he relieves by "letting off steam."

The Fish's Restless Mouth

Take, now, a very common object: a goldfish (or any common fish) in a glass globe. Notice that the fish continually opens and closes its mouth. You had already seen this action, but it is so usual that you had thought it hardly worth consideration? Or perhaps you had heard the phrase "to drink like a fish" and thought, naturally enough, that the fish was drinking? The truth is that the fish is breathing. It gulps

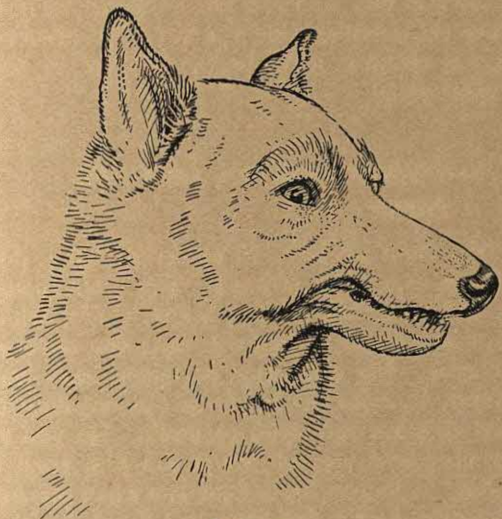


FIG. 1
Head of Wild Dog (Wolf)
Note the elongated face, and compare it with that of the cat.

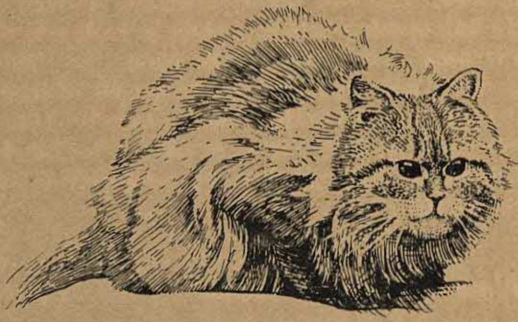


FIG. 2
A Cat Watching Prey
Note the short jaws, flat face, and forward-looking eyes.

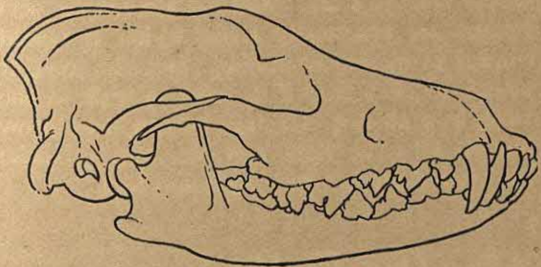


FIG. 3
Skull of Wolf
This shows the long jaws and numerous teeth.

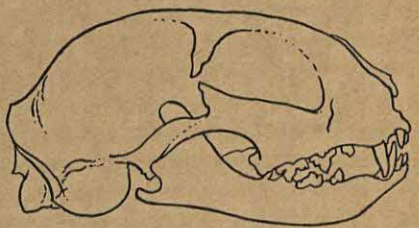


FIG. 4
Skull of Cat
This shows the short jaws and few teeth.

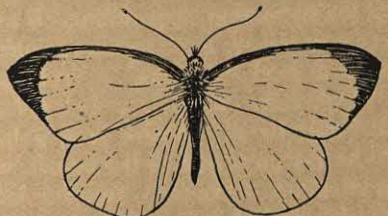


FIG. 5
A British Butterfly, the Common Cabbage White

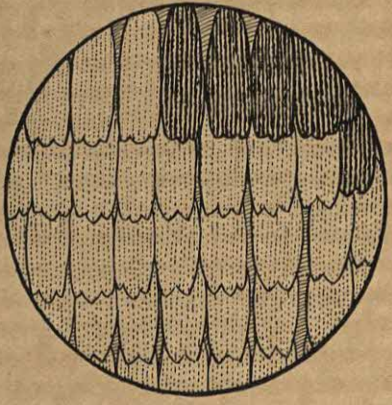


FIG. 6
Some Scales (magnified) from the Wing of Cabbage White Butterfly

in water, and this water comes out through a slit-like opening behind a plate at each side of the neck. Look behind the plate (the "gill-cover"), and a glimpse will be caught of some red feathery structures inside the mouth. These are the breathing organs or *gills*. The fish is continually passing water over its gills in order to breathe.

How the Fish Breathes

These comments will probably call forth the surprised inquiry, "But does a fish breathe?" or "Does it breathe water?" Here is an opportunity to explain that a fish (or any truly aquatic animal) must breathe just as we do; it breathes the gas called oxygen, as we must. But it uses the oxygen dissolved in the water. Pupils who have done a little chemistry can here usefully be reminded that water consists of oxygen and hydrogen. But the fish does not use the oxygen chemically united with the hydrogen; it uses only the oxygen dissolved in the water. A fish which cannot get enough oxygen from the water rises to the surface and tries to get it by sucking in air. Have you noticed that a goldfish kept in dirty water rises and gasps at the surface?

The Horse's Nostrils

These observations provide a natural and easy transition to other and related questions. Take, for example, the breathing of a horse. Have you looked at a horse's nose? Have you noticed its nose-openings or nostrils? Are they like those of a cat or dog? Very much bigger, of course, and more prominent and distensible: so prominent and distensible that they give quite a peculiar and characteristic expression to a horse's face. Well, have you ever observed a horse's nostrils after it has had a hard run? Have you noticed how widely they are distended, and how they quiver? Of course everybody has seen this, either in the street or at "the pictures." But you have not seen a horse pant as a dog or man would do, with open mouth. A horse pants through its nostrils, not through its mouth. The internal arrangements of a horse's throat prevent it from taking air fast enough down that way, and so it pants through its nose. Here is the explanation of a fact often observed but so common as to be thought not to need explanation.

Quadrupeds need not Learn to Swim

No doubt we have all observed that a dog, thrown into water, swims to shore, even though it has never seen water before. Cats, which naturally detest getting wet, can swim easily on occasion. Big cats, such as tigers, have been known to cross rivers. Even the ungainly ox and elephant can swim naturally. Do you remember how you felt when you first tried to swim? A human being flounders when put into the water for the first time, and if help is not at hand he may drown. He must previously be "taught to swim."

What is the reason of this? The answer is that the horizontal-bodied beast is in a natural position to swim. Thrown into the water, it simply tries to walk, and the actions so performed are practically those which it would employ in expert swimming. But the upright man is so built that if he tried to walk in the water he could not. He must be taught to throw himself into the right attitude, and to make the needful strokes with arms and legs.

Why a Duck Waddles

The duck is a bird which swims easily and naturally, but on land its walk is not graceful. Why does a duck waddle? Look at its legs, and notice that they are placed rather far back (farther back than in, say, a fowl). A duck is adapted for swimming by paddling. Its webbed feet offer a relatively large surface to the water, and so get a good "purchase." To bring these feet into effective action for swimming they must be well back. (Where is a ship's propeller? At the after end of the vessel, where it is most effective, of course.) But the feet must not be so far back that they cannot also be used for walking. The result of the whole arrangement is that on land the duck's walk is a characteristic waddle.

Why Rats Nibble

Rats (and other rodents, such as mice, rabbits, and squirrels) are continually gnawing. Every boy knows that a pet rodent makes short work of a wooden cage. Look at the mouth of any rodent, and notice that its front teeth are like chisels. Such teeth can be used to chisel the shells from nuts, the bark from trees, the husks from grain, etc. They are so much used that (unlike our teeth) they must always be growing, for otherwise they would wear away. But there is danger that always-growing teeth may overgrow. The rodent continually gnaws, and so keeps its teeth just right. If it is prevented from gnawing, it suffers from overgrown teeth.

The Ox's Belly and the Cat's

Have you noticed that cats (domestic cats, lions, tigers, and others) have as a rule lank bellies, whereas such animals as oxen, deer, and antelopes have as a rule full "tubby" bellies? Remember that the first-named sorts of animals are carnivores (flesh-eaters), whereas the others are herbivores (plant-eaters). A carnivore does not need much intestine to deal with its concentrated food. But an ox, feeding on less nourishing grass and small herbage, of which it must devour large quantities, needs voluminous intestines. Hence the cat's lank belly, and the ox's full one.

The Ruminating Ox

Observe for a few moments an ox which is lying in a field. You cannot help seeing that its jaws are continually chewing. The animal is *ruminating.* Oxen, antelopes, deer, camels, and llamas all have this ruminating habit. Why need such creatures chew so determinedly?

An ox browses, "bolting" its food in quantity with little chewing. It then moves off to a quiet place, lies down, and re-chews the food at leisure. It is perfectly still for a moment; then a convulsive movement is observed in its throat, and a small mass of food is forced back up the food-passage into the mouth, where it is thoroughly chewed. It is then swallowed again, going through the stomach into the intestine. Another portion of food, which has been held in a special part of the stomach, is forced up, and so the process goes on.

It has already been remarked that ancestral habits reveal themselves every day in tame cats and dogs. Such habits are revealed also by ruminants. In a wild state these animals are the prey of carnivores (think of a lion killing an antelope). If a ruminant stays to chew the great quantities of green stuff which it must take, it is exposed to attack whilst it is eating. But if it can "bolt" its food and chew it at leisure, at the same time keeping a watch for possible enemies, it is at some advantage. Tame oxen in a field are in little danger of attack, but they retain the ancient habit of ruminating and watching.

Note, too, that such creatures need to chew more than usually well, for grass is hard siliceous stuff, and if it is to be digested it must be thoroughly ground up.

The "Dust" from a Butterfly

Every child has caught and handled a butterfly or moth, and has noticed the "dust" which comes from the creature on to the fingers. This supposed dust is composed of a multitude of very tiny flat objects, called *scales,* suggesting in some ways the scales of a fish or reptile. The colours of the insect reside in the scales, which are most beautiful objects when seen under a microscope. The scales are sufficiently well attached to the insect, but they cannot withstand the violent rubbing of the human fingers.

Why the Eel is Slippery

"As slippery as an eel" is a common phrase. Anybody who tries to pick up a healthy living specimen will quickly learn that it is difficult to seize the fish, and still more difficult to hold it. Why is an eel so slippery? To answer this question we must know the creature's habits. It lives in the stony, sandy, or muddy beds of seas or ponds (for it can live in either salt-water or fresh-water), thrusting its way by a serpentine motion of its body through the bed. Observe that the fish is long and narrow as well as smooth and slippery. A long slippery body is obviously well fitted for movement through gravel and sand. Would an ordinary fish (such as a goldfish) be fitted for such a mode of life? Or do you think its somewhat torpedo-shaped body is better fitted for swimming?

The Flat-bodied Plaice

There are other fishes besides the eel whose forms differ from that of an ordinary fish. The plaice, to mention but one example, is flattish. It is brown on one side, and white on the other. The meaning of this curious form and colour seemingly is that the plaice, which usually lives in sandy-bedded seas, is able to escape in some measure the unwelcome attentions of enemies by resting flat on, or partly in, the sand, the brown side of the fish being uppermost and the white side below. Both the eyes are on the brown (uppermost) side, where they can both perform their functions, even when the fish is lying flat on the sea-bed.

It is a remarkable fact that when the fish is very young its two sides are alike, and its eyes are in the usual positions, but it soon begins to change.

Snakes' Tongues are not Stings

Have you watched a live snake, in the school vivarium, or at the "Zoo," or elsewhere? If so, you have doubtless seen the slender forked organ (shaped somewhat like the body of a boy's catapult) which at intervals flickers rapidly in and out of the reptile's mouth. This organ is the tongue. Many people hastily assume it to be the sting, an opinion curiously hard to dispel. When the snake creeps, or is alarmed, or sees food, or is in any way excited, its forked tongue appears. The tongue is a highly sensitive feeler, with which the reptile touches and tests the various objects around it. If you have an opportunity to look very closely at the head of a snake, notice that there is a little notch in the front of its upper jaw. Through this notch the tongue is protruded.

The true stings of a snake (supposing it to be a poisonous kind, of course) are certain large teeth, sharp as needles, which are in some species grooved and in others hollow. The poison, forced by the movement of the jaws from a poison-gland, is squirted down the teeth and into the wounds which the teeth make when the victim is bitten.

The Elephant's Big Nose

Everybody knows that an elephant has a trunk and two ivory tusks. Even a casual glance at the trunk will show that it occupies the place of the nose in other animals. It is, indeed, a very long and big nose (or, to speak more precisely, nose and upper lip combined), the openings of the nostrils being at its end. The mobile trunk can be used as a hand, to lift a man or a tiny object. The tusks are huge organs (though small or absent in captive present-day animals), and have been known to reach over 8 ft. in length and to weigh 170 lb. apiece. On examination of the skull of the animal, it is easy to see that the tusks take the place of what in other creatures would be upper front (incisor) teeth. They are, in fact, enormous front teeth, which project from the mouth and can be used as formidable weapons.

Thus, instead of saying that an elephant is a huge animal with a trunk and two tusks, we may say that it is a huge animal with a very big long nose, capable of being used as a hand, and two enormous projecting front teeth. Let it be supposed that we have never seen an elephant. Let it further be supposed that we are told for the first time that there is an animal answering to the second description. Should we not believe it to be (as it is) the most surprising creature which has ever lived?

Conclusion

The foregoing are a few examples of lessons which can be based upon observation of isolated biological facts. The ambition of the true teacher is to "excite the desire to know." One way to achieve this is to throw unexpected light on familiar things.

GEOLOGY

A Branch of Nature Study

IN the nature study lesson it has often been the custom to confine the attention of children to the animal and vegetable kingdoms and to practically neglect the mineral kingdom. Now that the geography taught is so largely "human geography," there is a tendency to omit the physical side, and to forget the numerous occupations and industries which depend upon the products of the earth's crust, such as clay, sand, granite, marble, slate, ores of metals, and other useful and necessary minerals such as salt, gypsum, asbestos, and mica. Simple talks on the occurrence, mode of formation, and uses of various stones and minerals may form a valuable basis for the geography and science lessons. Stones, rocks, minerals, and fossils are easily collected in great variety—especially by town children—because they are brought from all parts for a great variety of purposes. Children love collecting and labelling specimens and with a little encouragement they will make quite useful collections.

A simple course in geology as indicated briefly here and more fully in *Wonders of the Earth's Crust* (Pitman, 2s. 6d.) will show how the structure of the earth's crust influences water supply, coast erosion and protection, the distribution of population, and the industries and occupations of the people, and why certain large tracts of land are left uncultivated and almost unpopulated.

The development of many districts in many countries has been hastened by the discovery of valuable minerals such as gold, diamonds, tin, etc. Australia, New Zealand, California, Alaska, Nigeria, South Africa, and Labrador are good examples of this. The search for the products of the earth's crust causes prospectors for gold, oil, and other minerals to go to the most unknown and uninviting parts of the earth.

A slight acquaintance with fossils links up the lessons with those in biology and history, and gives the child some idea of man's place in time compared with that of other living creatures.

There is scope for practical work in school which may consist of: making a school or private collection, examination of stones and photographs collected, examination of a simple geological map, making of models, and simple experiments which will be introductory to a course in chemistry and give a little idea of how scientists and prospectors may determine what substances are present in any particular rock.

Perhaps the main value of the course may be that the child will gain an additional interest in the rocks seen during holidays and excursions to the seaside or country. He will observe many things and go to many picturesque spots which otherwise he would not notice or visit.

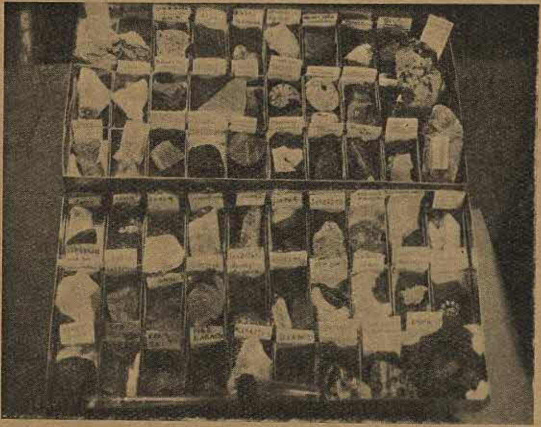
A School Collection

The child should be encouraged to make a private collection of stones which he should label with the names of the localities where found and the uses to which they are put; but at the same time he should contribute specimens of special interest to the school collection. Unlike flowers and living creatures, stones may be easily stored and kept in good condition without much trouble. Good, useful collections may be stored in quite a small space, to be used to illustrate geography, chemistry, and geology lessons.

It is astonishing the number of people who have collected stones which are of interest from various places visited during holidays. These will be brought to school and shown to the teacher. Gardens, rockeries, coal cellars, ploughed fields, excavations and road cuttings of all kinds, the demolition of houses and shops, and even open common land will provide many specimens even when more valuable visits to quarries, sand and clay pits, colliery tips, or seaside sections are impossible.

Apparatus Required

More important than apparatus is the observant eye. Much useful work can be done with a hammer as the only piece of apparatus, but a cold chisel, a pocket-knife, a bottle of hydrochloric acid, a magnifying glass, a collecting bag and a supply of newspaper, empty matchboxes, and tins would be quite a good equipment for the young enthusiast. Empty matchboxes are easily arranged in bigger, shallow boxes or drawers, and it is remarkable what large specimens may be placed in them and suitably labelled on a strip of paper arranged as in Fig. 1.



H. E. T.

FIG. 1

A Collection of Stones made by a Scholar (*Age* 12)

Igneous Rocks (*Fire-formed*)

The original earth's crust was probably formed from the solidification of molten material. Similar rocks can be seen forming, in volcanic districts, now. Steam and other gases generated within the crust eject masses of lava from holes or cracks called volcanoes. The heaps of "ashes" and lava around the vents often form large hills. The lava may form pumice on the surface of the stream, obsidian (a glassy stone) when escaping gases do not form holes, or basalt if crystals have time to grow before solidification occurs. In many places in Britain are found similar rocks, which were ejected from volcanoes millions of years before the advent of man, e.g. Giant's Causeway, Staffa, and many other places shown on the geological map. Basalt is often used in road construction and pumice in the house, so these stones can be added to the collection.

Granite—a stone largely used for curbstones, gravestones, and decorative building—is an igneous rock which cooled within the crust and thus had time to form crystals large enough to be seen with the naked eye. Its main constituents are quartz, felspar, and mica, but other minerals are often present as well. Cornish and Devon granites usually have grey quartz, white felspar, and brown or black mica. In pink granites the felspar is pink. Some other deep-seated igneous rocks contain large crystals of mica, which split into thin transparent slices that are useful in the electrical trade, and form a substitute for glass in anthracite stoves, etc. Sometimes large crystals of pink or white felspar are formed, and we have the ornamental rock called porphyry.

Igneous rocks which have cooled within the crust and have since been exposed by denudation are known as plutonic rocks. There are many varieties which may be found in many parts of the British Isles (see geological map). Children

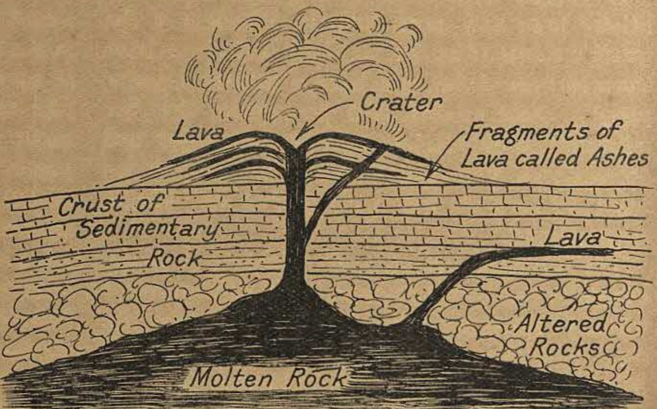


FIG. 2

Diagram of Active Volcano

should examine specimens of granite or other easily found igneous material. The igneous rocks of N. Wales, Charnwood, Malvern Hills, etc., are largely quarried and used for road construction in those parts of Britain where the local rocks are mainly soft sandstones, clays, and marls.

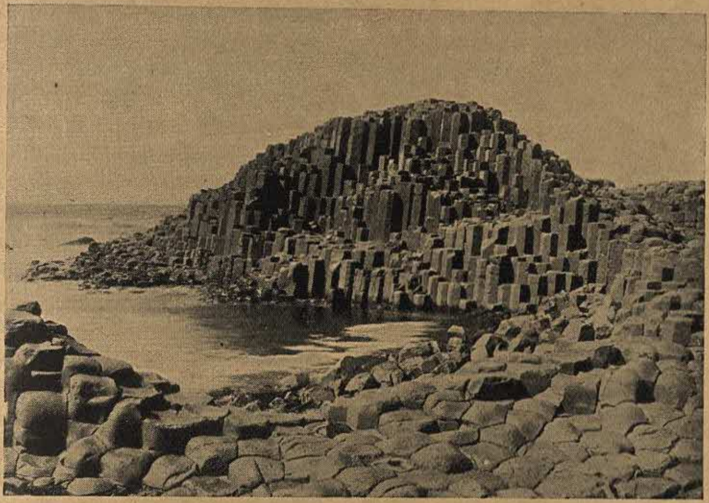


FIG. 3
The Giant's Causeway

SPECIMENS FOR COLLECTIONS. Granite, pumice, basalt, porphyry, mica, quartz, felspar, and any other local varieties of igneous material. Slag may be included as an artificially formed igneous rock.

Nature as a Sculptor

Revision lessons on the way nature acts as a sculptor may be introduced here. Since the first crust was formed, natural forces have been continually wearing away highlands, carving gorges and valleys among the hills, and removing material from higher to lower levels, to form alluvial plains, deltas, sand-banks and beaches, and to make new rocks from the remains of older ones.

Nature's "Tools"

1. *Frost.* Ten parts of water form eleven parts of ice. Water freezing in cracks may act as a wedge to break off small pieces of rock: e.g. screes in mountain districts, at the base of cliffs and in quarries.

2. *Streams and rivers* act as chisels, carving out more or less V-shaped valleys and forming mud and sand by wearing away their banks and beds. (Note—streams of rain-water cut grooves in gravel paths.)

3. *Waves* act as battering-rams against cliffs.

4. Glaciers use stones, embedded in them, to scour their sides and beds.

5. *Plants* force their roots into the cracks of rocks and, by their growth, widen them.

6. *Air* forced by waves into cracks and caves may act almost as an explosive.

7. *Wind* may carry sand or dust which gradually wears and polishes rocks upon which it impinges.

8. *Water* containing carbon dioxide is acid and has a great solvent power, thus widening cracks and forming caves, especially in limestone areas.

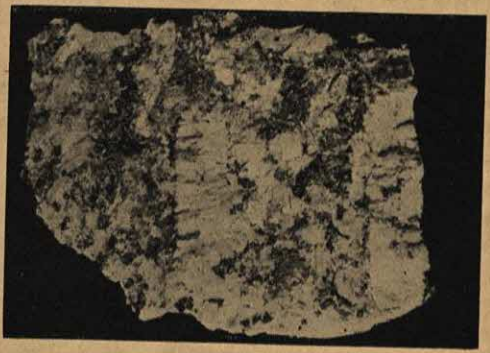


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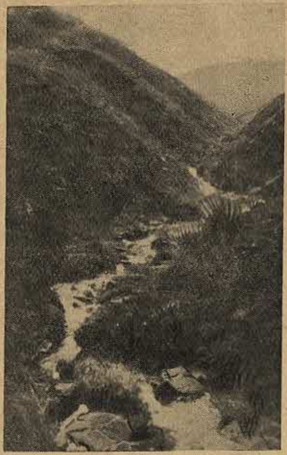
FIG. 4
Cornish Granite
Large white crystals of felspar, black mica, and grey quartz.

Means of Transport

1. *Rivers* carry mud, sand, and gravel from high to low levels, filling lakes and forming sand-banks, bars, deltas, etc.

2. *Glaciers* carry rocks and stones dislodged by frost to form terminal moraines, etc.



R. W. L., Melbourne

FIG. 5

A Mountain Stream Cutting a V-shaped Valley

3. *Icebergs*, broken from glaciers reaching the sea, carry rock debris to sea and drop it in the ocean.

4. *Winds* carry sand and dust, forming sand-dunes and deposits of loess.

5. *Waves* and *sea-currents* sort out pebbles, sand, and mud deposited on the shore, and form beaches, storm beaches, layers of mud, etc.

Questions on dredgers, the overflow of the Nile, deltas, weathering of buildings, painting of stonework, deserts, mineral springs, etc., will be helpful here.

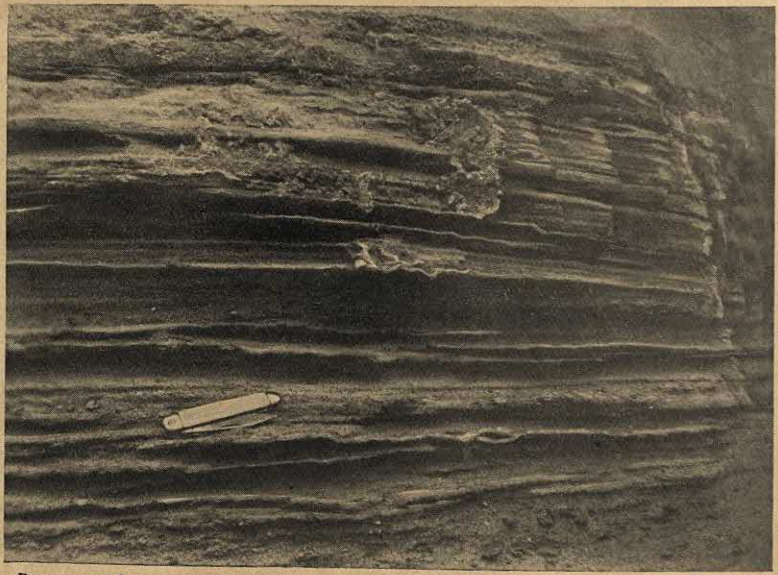
Aqueous, Sedimentary, and Stratified Rocks

Rock debris carried to the sea is deposited as sediment in strata under water. These in time become rocks. Such rocks may be studied by examination of the sands, sandstones, clays, limestones, and chalk which form such a large proportion of our rocks and have so many uses.

SANDS AND SANDSTONES. These often show that the grains have been deposited in layers which vary in colour and texture. Such layers have been deposited under water at different times and under different conditions. Hard sandstones, split along these layers, often show shining specks of mica upon their fresh surfaces. The mica, derived possibly from some igneous rock, has been deposited on sand, which is often composed largely of quartz grains derived from igneous material or other sandstones. That sandstones were sometimes deposited under shallow water conditions is shown by the preservation of ripple-marks, suncracks, footprints, and the pitting made by raindrops (Fig. 10).

Note. Sandy beaches and sand dunes are sandstones in the making.

CLAYS. These are formed of very small particles of rock rubbish and often contain kaolin



By courtesy of A. L. Leach

FIG. 6

Wind Eroded Sandstone

Wind blows away looser sands more easily than those bound together by clay.

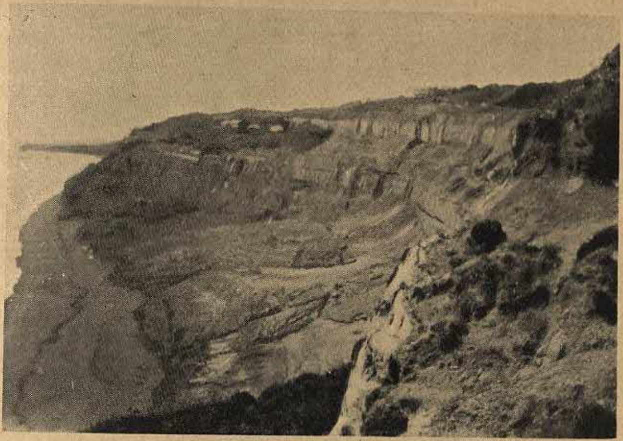


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FIG. 7

Coast from Blackgang Chine, Isle of Wight

The fans of sand and mud have been brought down from the cliff by tiny streams. The sea washes the front of the fans and spreads the sand and mud on the shore.

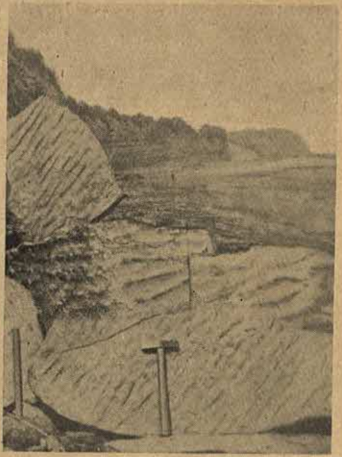

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FIG. 10

Ripple Marks on Sandstone

The slabs which fell from the top of the cliff were propped up for photographing.

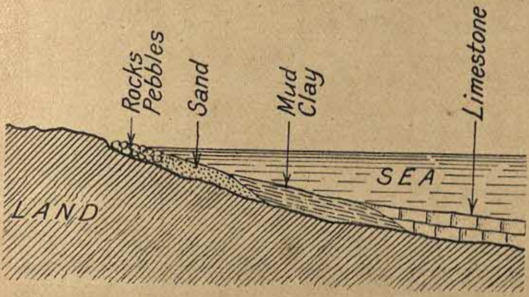

FIG. 8

Nature's Rubbish Laid in Layers on the Sea Floor

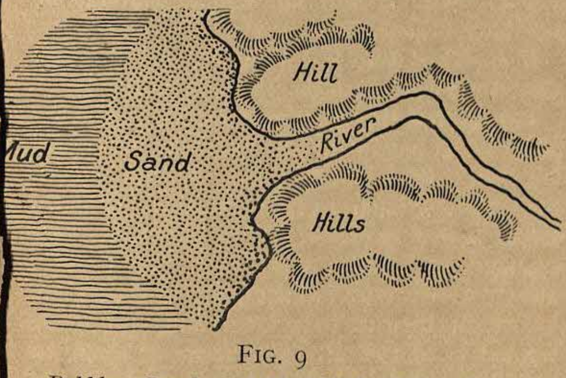

FIG. 9

Pebbles, Sand, and Mud Deposited under Water by River

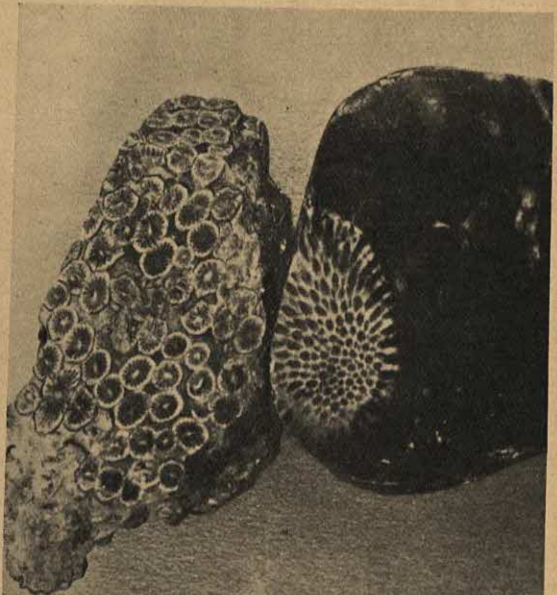

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FIG. 11

Fossil Corals in Limestones

obtained originally from the decomposition of felspar in igneous rocks. They are deposited in estuaries and in the sea partly through the action of salt water upon suspended matter. When clays are dry they are powdery, but when wet they are plastic and impermeable to water. Clays, although so soft, are to be considered as rocks. Some clays may contain sand and be called sandy clays or clayey sands.

Limestones

These may be formed in a variety of ways—

1. By deposition from water containing limestone in solution, e.g. stalactites and stalagmites, tufa, etc.
2. By coral polypes, e.g. the Barrier Reef in Australia, Coral Islands.
3. By deposits of the shells of foraminiferae, globigerina, etc.
4. From banks of shells of molluscs.

Note. Globigerina in chalk; corals in mountain limestone, coral rag, and oolite; and shells in many limestones.

Limestones are fairly soluble in water containing carbon dioxide, hence: large cracks and caves in limestone areas—mineral and petrifying springs—hard water — stalactites — crystals—fur in kettles.

Limestone effervesces with hydrochloric acid, giving off carbon dioxide. This forms a convenient quick test for limestones.

Uses of these Aqueous Rocks

Only a short summary of the many uses can be given here.

Sands and Sandstones

Houses, bridges, paving stones, road metal, surface dressing of tarred roads, foundry sands, glass making, mortar, concrete, abrasives.

Clays

Kaolin for china. Impure clay for bricks, tiles, chimneys, stoneware, earthenware, sewage pipes, decorative tiles, firebricks, paint, Fuller's earth.

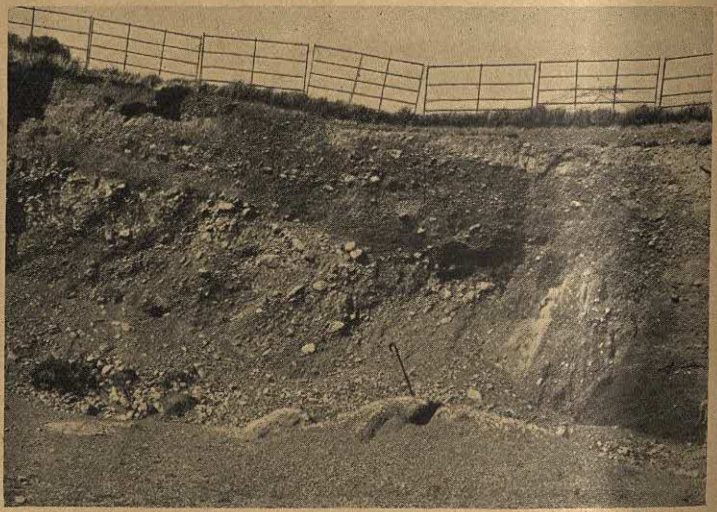
Limestones

Building stones, road metal, lime for various purposes cement, lining for furnaces, flux, etc.

Limestones, clays, and sandstones have been formed in many different ages, and under many different conditions. They are therefore found in many parts of Britain and are of different hardness, colour, and texture. Because of these differences some are more suitable for one industry or use and some for another.

Earth Movements

If there had been no reconstruction, all hills would be worn away and shallow seas filled with sediment by now. Aqueous rocks formed as soft sediments now appear inland at great heights. Slow crustal movements throughout ages have brought this about.



By courtesy of *H.M. Geological Survey*

Fig. 12

Glacial Sands and Gravels, Anglesey

Note. Time from Moses till now is only a *very* short time when considered geologically.

Throughout ages great movements have taken place which have bent and lifted the horizontal layers of sediment formed under the sea, so that they are now found as tilted, vertical, or folded strata above sea-level. These layers, as they emerged and since, have been partly worn away and new ones formed many times, so that in Britain there are to be found remains of rocks formed in almost all ages. Some of them are very tilted and folded, others more gently, and of others only fragments remain.

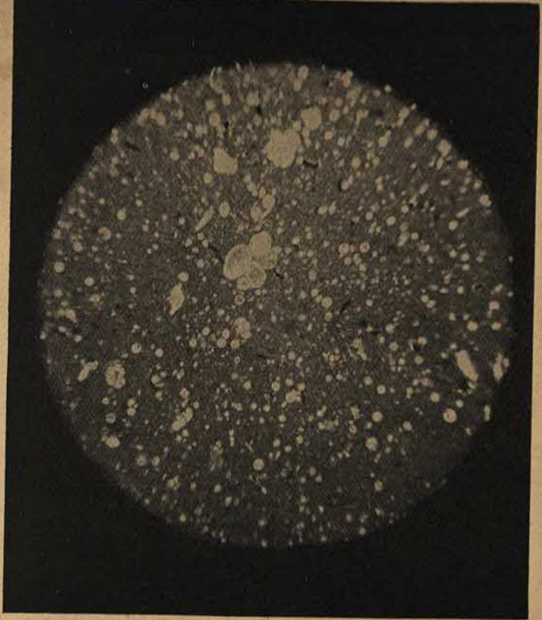


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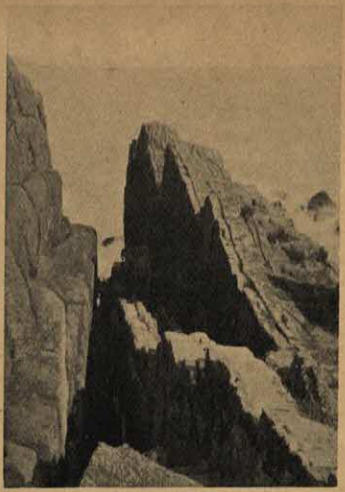
FIG. 13

Photomicrograph of a Section of Chalk showing Foraminiferae



By courtesy of *H.M. Geological Survey*

FIG. 15

Old Castle Head, Manorbier, Pembroke

Vertical strata—sandstones and mudstones. The softer layers have been worn away more rapidly than the harder ones.

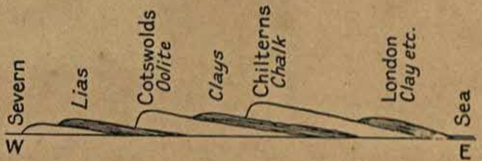
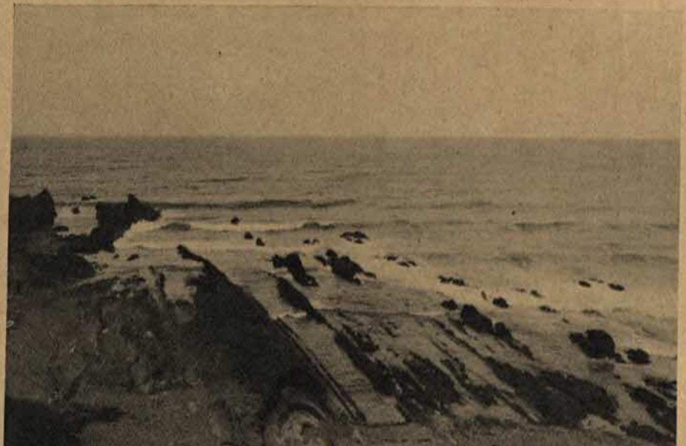


FIG. 14

Section Across England

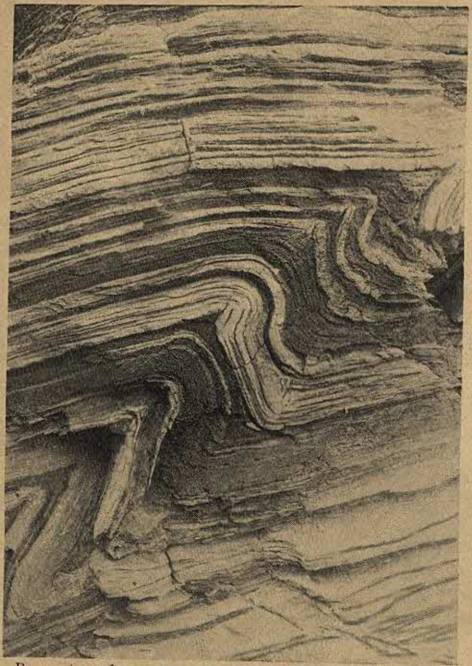


By courtesy of *G. W. Railway*

FIG. 16

The Whale Back Rock, Bude

An anticline being worn away by the sea. The harder layers form little escarpments to the right of the Whale's Back.



By courtesy of S. Hall.

FIG. 17

Contorted Strata, Boscastle

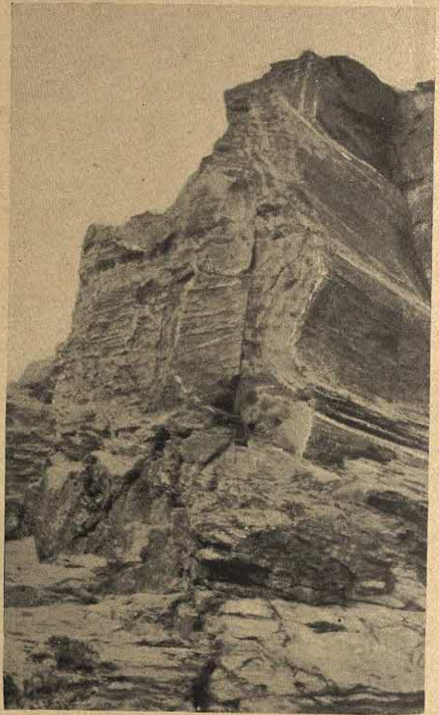


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FIG. 18

Gwithian, Cornwall

Rocks folded into anticlines and synclines and now almost vertical.

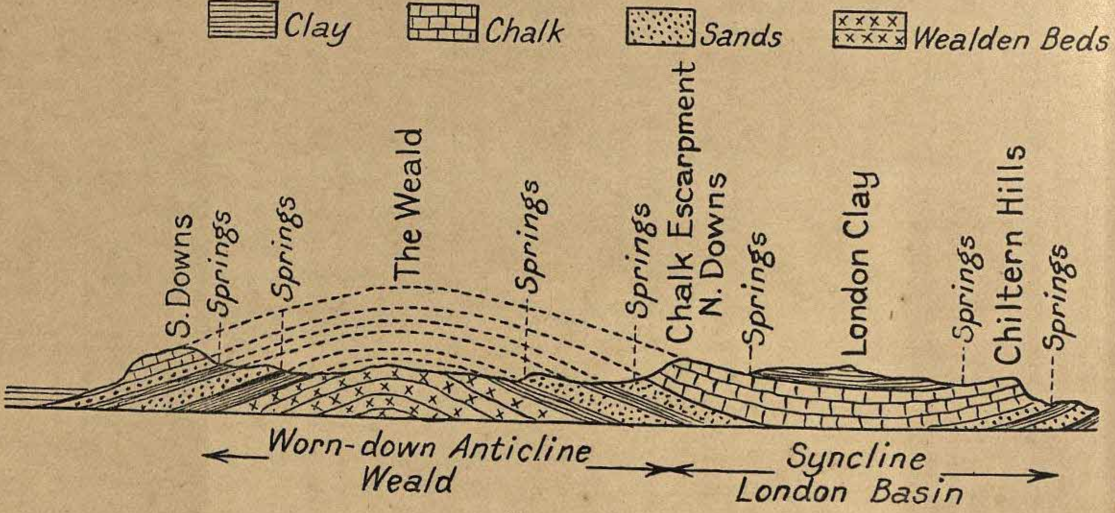


FIG. 19

Diagram of Syncline and Anticline

Reference should be made to submerged forests, raised beaches, inland cliffs, and the lost lands of East England, to show that such movements are still going on. Sections of the London Basin, Weald, Pennine Chain, Forest of Dean, etc., make useful illustrations of folding and subsequent denudation and present opportunities for explaining escarpments, dip-slopes, and exposure or disappearance of layers in various places.

Bending of rocks sometimes causes them to crack and slip along planes called faults. Movements along faults produce earthquakes: e.g. Scottish earthquakes are small shocks due to movements along old faults. Any local faults should be described or visited. Discuss the Great Rift valley of Africa, which affords a good example of faults.

Hardening of Soft Sediments

Sands, clays, and limestones were laid down as loose sediments, but when examined they are often hard and closely bound together. This change is caused in several ways—

1. By pressure of the new layers, or pressure which has bent and folded the layers.

2. By heat of igneous rocks poured out on top, or approaching from below.

3. By desiccation of the sediment. *Note:* dried mould from a neglected flower-pot becomes a solid mass. Muddy roads have hard ruts when dried.

The stone-mason and slate-splitter prefer to work with rock which has "quarry water" in it.

4. By cement: consisting of silica, limestone, or iron compounds. Limestones may be cemented by crystallization of calcium carbonate. Sandstones may be cemented by any of the above cements and termed siliceous, calcareous, or ferruginous. Compare nature's method of forming conglomerate with our method of making concrete.

Note. (*a*) Effect of iron-pan—sand cemented with iron-oxide—upon agriculture. It forms dry soil in summer but marshy soil in winter. Roots only penetrate it with great difficulty.

(*b*) The kind of cement affects the usefulness of the stone for building or road-metal.

Metamorphic Rocks

A geological map of Scotland shows much of the rock is metamorphic, i.e. rock changed from its original character. The commonest useful metamorphic rocks are slate and marble; but serpentine, an altered igneous rock, is used for ornamental purposes, and schists and gneisses locally for building, roads, etc.

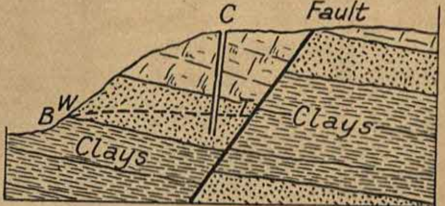


FIG. 20

An Intermittent Spring

Diagram shows a fault producing an intermittent spring at B. C = well; WT = water table.

Metamorphic rocks have been changed by heat of volcanic or plutonic material, by gases or liquids given off from such material, or by pressure due to overlying layers or earth movements.

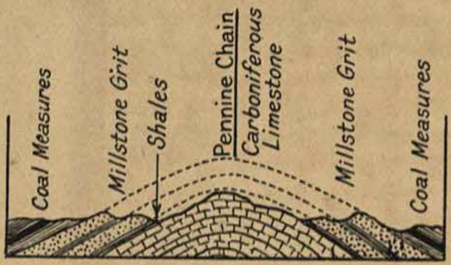


FIG. 21

Section Across Pennine Chain

Note Dip of Coal Measures.

Slate is usually a clay altered by great pressure so that the particles have rearranged themselves in layers which causes it to cleave or split in one particular direction. Note the slate industry and its importance to the community.

Marble, an altered limestone found near igneous masses, is of great use to the sculptor and for decorative purposes because of its even texture. Compare it with limestone. Test it with hydrochloric acid. Note the absence of corals, etc. Many decorative limestones are sometimes called marbles by stone-masons although they have not been altered. E.g. Cotham marble, Purbeck marble, landscape marble.

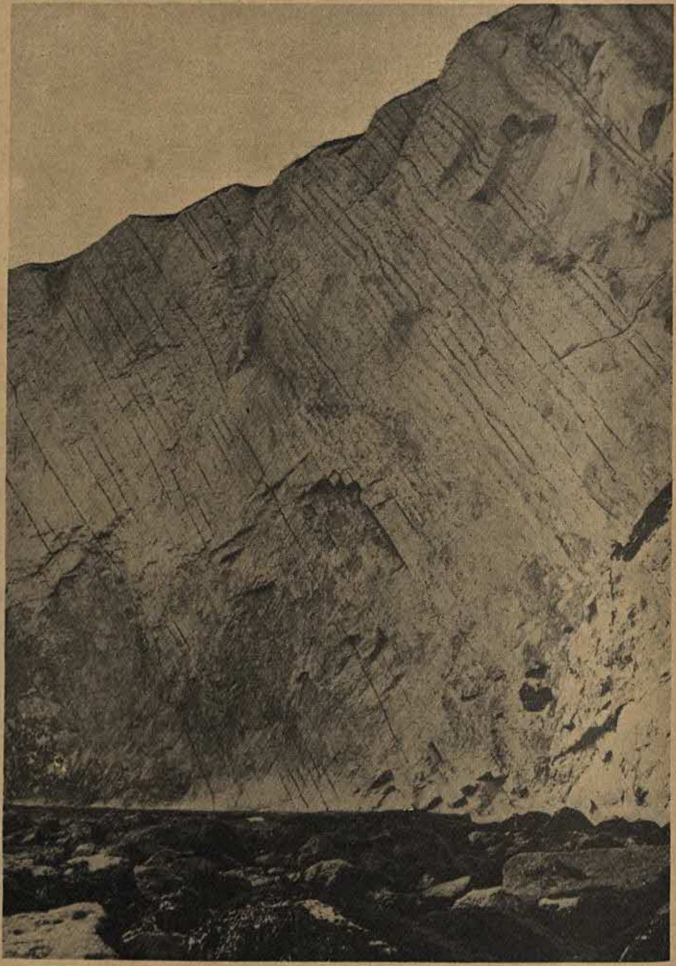
Schists and gneisses are banded rocks containing quartz, felspar, and mica, with a parallel arrangement of the particles. They have been formed, as the result of great heat and pressure, from either sedimentary or igneous rocks. They are found in great patches in Scotland, Southern India, Africa, Canada, and many other places. The mica in them often makes them glimmer in the sunlight.

Flints

One of the commonest stones in south-east England is the flint found in chalk, gravels, sands, and garden soil, or on the seashore and on open heaths. Flint, formed as hard nodules in the chalk from silica which was once part of siliceous sponges or microscopic radiolarian shells, is left behind when chalk is worn away. The removal of chalk from the Wealden anticline left many flints which now appear in the more recent deposits of clays, sands, and gravels which were formed in the London and Hampshire basins. In the chalk, flints have white coats, but in later-formed layers, these coats have often been removed and the flints become changed in colour.

Broken flints may contain tiny quartz crystals, chalcedony, fossil sponges, fossil shells, or tiny foraminifera. Prehistoric man selected flints for his implements because they are very hard and break with very sharp edges. Thousands of flints flaked by man have been found scattered about Britain in gravels, in ploughed fields, and on open heaths. Children should be encouraged to chip flints into definite shapes, but warned of the sharp splinters. Sharp edges may be used for sharpening a pencil.

More recently flints have been used in flint-lock guns; with steel and tinder box for obtaining a light; in the manufacture of flint glass; for glazing pottery. They have been used for building churches and walls, and are still largely used for roads, gravel paths, and concrete. Onyx, Jasper, Agate, and Chalcedony are semi-precious forms of silica very similar to flint, which is itself silica.

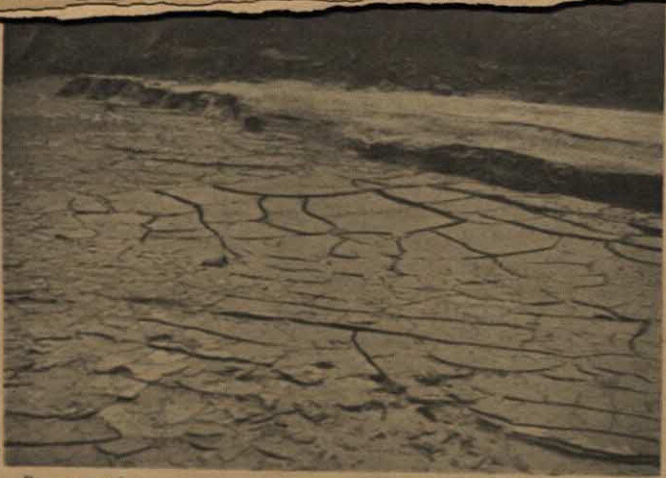


By courtesy of *H.M. Geological Survey*

FIG. 22

Culver Cliff, Isle of Wight

Lines of dark flints in inclined layers of chalk.



By courtesy of *H.M. Geological Survey*

FIG. 23
Sun-cracks in Peaty Mud, Torside Reservoir, Cheshire

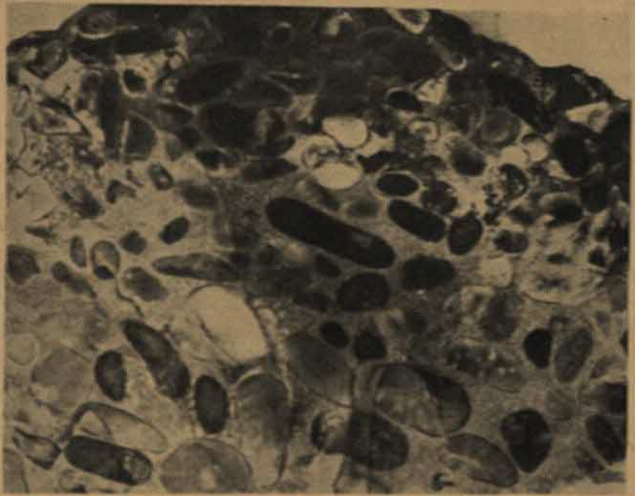


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FIG. 24
Hertfordshire Pudding Stone
Pebbles cemented together with silica.

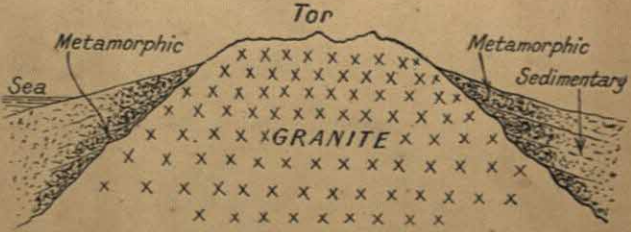

FIG. 25
Sedimentary Rocks Altered by Contact with Igneous Material

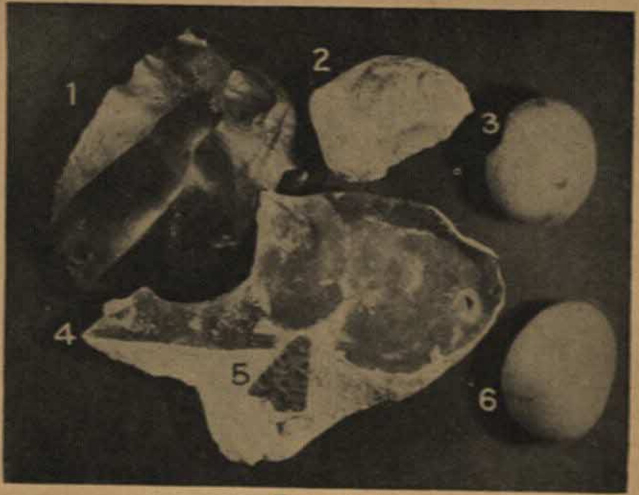

FIG. 26
Flints

1 and 5. Flint implements.
4. A broken flint from the chalk.
2. A pot boiler.
3 and 6. Pebbles from Shirley Hills, Croydon.

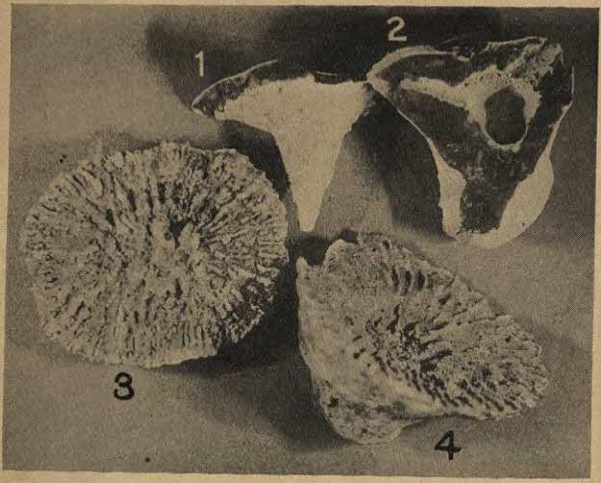

FIG. 27
Sponges in Flints
1 *fits into the hole of* 2. 3 *fits on top of* 4.

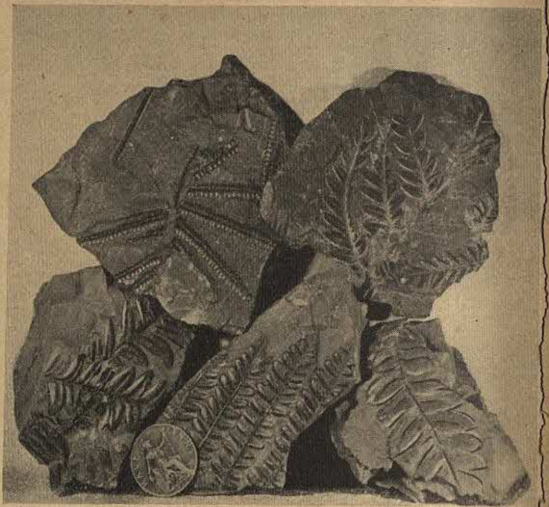

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FIG. 28
Leaves of Coal Plants from Bristol Coalfield

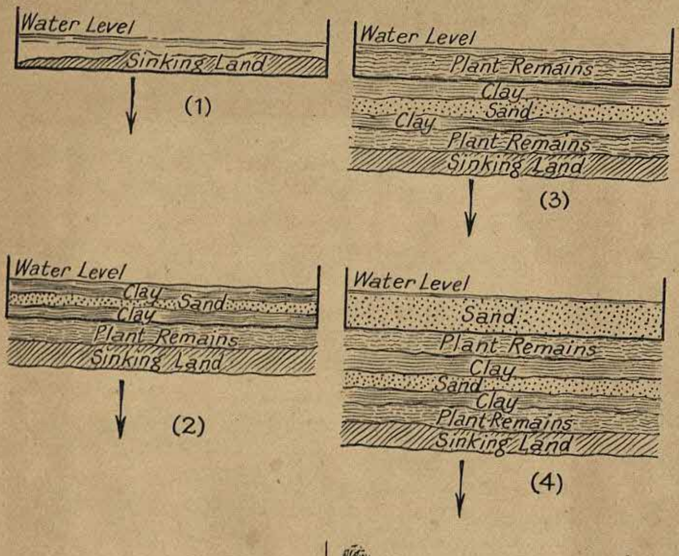

FIG. 29
Formation of Coal Measures
In course of time 1 *becomes* 2, *then* 3, *and later*

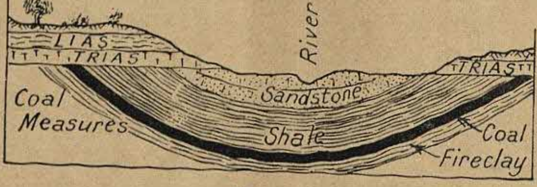

FIG. 30
Coal Measures in a Syncline Overlain by More Horizontal Strata

Coal

Remains of plants, such as shown above, are often found in the shale brought up from a coal mine. The plants lived millions of years ago when the coal was being formed. Many of the leaves look like fern leaves, but they were really the leaves of tall trees which bore cones or spores. Plants then were different from those of to-day. Coal was formed in swampy districts, where the crust of the earth was slowly sinking. Large masses of brown or black vegetable matter thus accumulated in the swamp during many hundreds of years. A time came when the land sank still further and water filled the swamp covering the pulpy plant debris with layers of sand and mud. Fresh forests grew forming new layers in a new marsh which in turn became covered with sand and mud. This happened several times. At the end of the Coal Age the land sank more rapidly and great thicknesses of sand were deposited upon the whole series of layers. All this occurred millions of years ago, and since that time the layers have been folded, lifted above sea-level, partly worn away, and in many cases they have sunk again to be covered with thousands of feet of clays, sands, and limestones. Heat, pressure, chemical and bacterial action, have combined to change the pulpy, black, material into the most valuable of aqueous rocks known as coal.

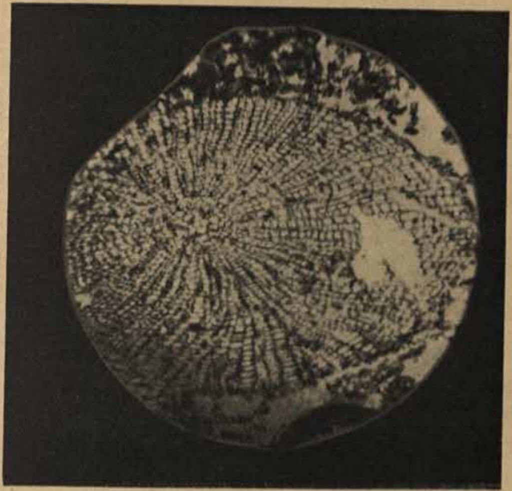

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FIG. 31

Photomicrograph showing Plant Remains in a Coal-ball

Observed Facts About Coal

1. Coal, like other aqueous rock, is found in layers and often splits along them.
2. Roots and trunks of trees, still in the position of growth, are found in layers of fireclay which underlie the coal.
3. Coal is often found in synclines, the anticlines having been worn away.
4. In the shales covering seams, many good specimens of leaves, cones, and spores of plants are preserved.
5. In coal bearing rocks shells somewhat similar to the mussel are found.
6. By careful skilful treatment, botanists have discovered plant fibres and spores in the coal itself.
7. In stony nodules—known as coal-balls in Lancashire—pieces of stems, leaves, spores, and roots are mixed together, and cemented with calcite. Thin sections of these show the minute cellular structure of the plants, preserved in perfect condition (Fig. 31).

Further lessons might be given on methods of obtaining coal, its great value in industry and for transport, the valuable by-products obtained such as gas, coke, fertilizers, oils, and the innumerable tar products including dyes, perfumes, medicines, photographic materials, chemicals, explosives, flavourings, saccharine, etc.

While examining coal, attention may be drawn to—

1. Shale—a hardened form of mud.
2. Thin layers of white calcite (limestone) found filling cracks in the coal.
3. The mineral known as "fools' gold" (iron-pyrites—sulphide of iron) which spurts when put on the fire, and gives rise to the sulphurous fumes noticed in railway tunnels.

Crystals and Minerals

A solution of alum, if allowed to evaporate slowly, will become saturated, and deposit some of the alum in the form of crystals. Crystals found in the rocks are often formed in a similar way, but sometimes they are formed from molten igneous material, e.g. crystals in igneous rocks.

Crystals grow by the addition of particles to their outsides and during growth they maintain a constant shape with sharp edges and flat faces. If they become crowded, one crystal may interfere with the growth of another as in granite, where the quartz only fills the spaces between the felspar and mica which crystallized before it. Quartz crystals are, however, found in hollows in granite, in veins and cracks in old rocks, and in flints. These quartz crystals are formed from water containing silica in solution.

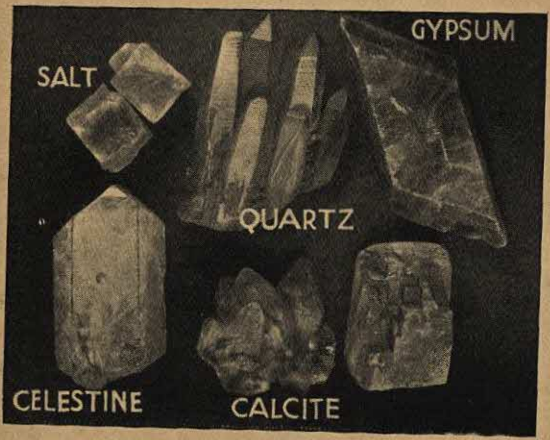

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FIG. 32
Crystals

Fig. 32 shows a cluster of quartz crystals which are almost colourless. Quartz is too hard to be scratched by a knife and hard enough to scratch glass. Commonly quartz is colourless or white, but it may be purple, yellow, brown, pink, or red. Rock crystal is the colourless glassy variety often wrongly called petrified water. Vein quartz is often found filling cracks in the older rocks and sometimes contains metallic ores or gold.

Calcite

Limestone, which has been dissolved in water containing carbonic oxide, is often deposited as crystals; and may be found filling cracks or holes in limestone rocks (e.g. caves in Derbyshire). The crystal form of limestone is known as calcite. It may be found filling fossil shells, or the steam holes of ancient lavas. Fig. 32 shows the shape of the crystal and also the cleavage form. Calcite may be scratched by a knife and it effervesces with hydrochloric acid. Thin white films of calcite may be found in the cracks of coal. A clear transparent variety, called Iceland spar, makes print viewed through it appear double.

Stalactites and stalagmites, found in caverns and hollows in limestone areas, are crystalline limestone but they rarely show crystal faces (Cheddar Caves, Kent's Cavern, Peak District, etc.) They have been formed by water, charged with limestone from the overlying beds, being slowly evaporated in the air of the caves.

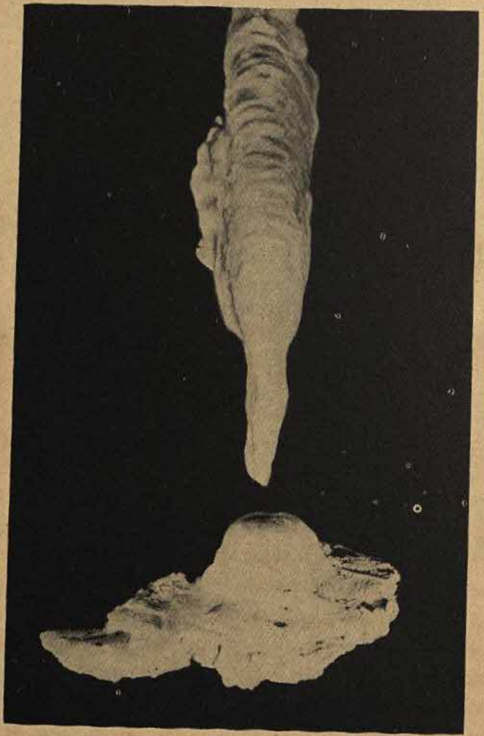


FIG. 33
Top: A Stalactite
Bottom: A Stalagmite

Gypsum

Gypsum or Selenite ($CaSO_4$) a crystal often found in clays, e.g. London clay, Wealden Clay, Lias Clay, etc., is glassy in appearance and readily splits in a direction parallel to the base of the crystal. It is soft and can be scratched with the thumb-nail. The massive form is heated to drive off the water of crystallization, and so form plaster of Paris useful in surgery, building, moulding, etc. The alabaster used for ornamental purposes is a white or prettily-coloured variety of gypsum. Satin-spar is a fibrous variety.

Salt

Crystals of salt may be obtained from sea-water by evaporation, but most of our salt is obtained from beneath a protective covering of impervious rock, as in Cheshire. It may be mined as rock-salt, or water may be poured into the bed of salt and, when saturated, pumped to the surface and the salt extracted and purified by crystallization. Salt is of importance as a condiment, but is more largely used in the chemical, soap, and fishing industries, and as a preservative for meat, vegetables, etc. Salt and gypsum are often found near one another, as they were formed by the evaporation of ancient seas and lakes. Cf. Lake Utah, Dead Sea, etc. Other salts are also found in some deposits, formed in this way. E.g. Stassfurt deposits contain potassium salts useful as fertilizers.

Fluor Spar (CaF_2)

Fluor spar—Blue John—is a mineral which crystallizes in cubes which may be found in Derbyshire. It is used for ornaments and decorative vases when prettily coloured; but also as a flux in smelting. The crystals are harder than calcite, but not so hard as quartz.

Celestine ($SrSO_4$) *and Barytes* ($BaSO_4$)

These are two heavy minerals used in the chemical industry. The shape of a celestine crystal is shown in Fig. 32. Celestine is found at Yate in Gloucestershire, and Barytes in Surrey, Derby, and elsewhere. They may be readily distinguished from quartz, calcite, and gypsum by their weight.

Jewels

The precious stones, diamonds, rubies, sapphires, emeralds, garnets, etc., are crystals of minerals which are hard, pretty in colour, reflect light well, and are sufficiently rare to make them desirable. When used as jewels they are cut so as to refract and reflect light as much as possible from the back of the stone. Dark coloured and imperfect jewels are useful because they are hard. Good glass-cutters often contain a fragment of diamond, ruby, or sapphire. These and other jewels are often used in good watches because they are hard and are not worn away by the moving spindles. The diamond is the hardest of all stones, and dark-coloured pieces are used in drills for rock boring. The natural crystal shape is similar to that of an alum crystal, but the faces may be slightly curved. Sapphire is a blue crystal of aluminium oxide and the ruby is a red variety of the same mineral. Corundum or emery is a massive dark-coloured variety used as an abrasive.

MOHR'S SCALE OF HARDNESS

10. Diamond.
9. Sapphire (Emery).
8. Topaz.
7. Quartz.
6. Felspar.
5. Apatite.
4. Fluor spar.
3. Calcite.
2. Rock Salt or Gypsum.
1. Talc (Tailor's Chalk).

One of the simple tests used when examining minerals is to find their relative hardnesses.

The recognized scale is given above, where hardness (10) is the diamond and hardness (1) is talc. Minerals of a given number will be scratched by those of a higher number and will scratch those of a lower number.

A rougher means of determining hardness is always available—

2·25 = Thumbnail.
5 = Window glass.
4–6·5 = Steel of pen-knives.
7 = Quartz or flint.

Ironstones

Iron pyrites ("fools' gold") is a golden-yellow sulphide of iron often seen as thin films on coal and as crystals or nodules in other rocks. One nodular form found in the lower layers of the chalk is generally called marcasite, but has recently been proved by X-ray analysis to be pyrites. This type of nodule is often quite wrongly called a meteorite or a thunderbolt. Crystals of iron pyrites may be cubes or as shown (Fig. 35). They cannot be scratched by a knife. Iron pyrites is chiefly used as a source of sulphur dioxide, not as an ore of iron. Haematite or "kidney iron ore," a pure oxide of iron, is one of the best iron ores. It marks unglazed porcelain, leaving a blood-red streak. Limonite, another form of iron ore, leaves a yellow-brown streak. The Cleveland iron ores and those of the Midlands are limestones of which some of the calcium carbonate has been replaced by iron carbonate. These are our chief ores of iron. Iron compounds are commonly distributed among the rocks, forming the colouring matter in many cases, and the cementing medium in others. Iron-pan, a layer of sand cemented by iron oxide, formed a short distance below the soil, spoils the land for agriculture.

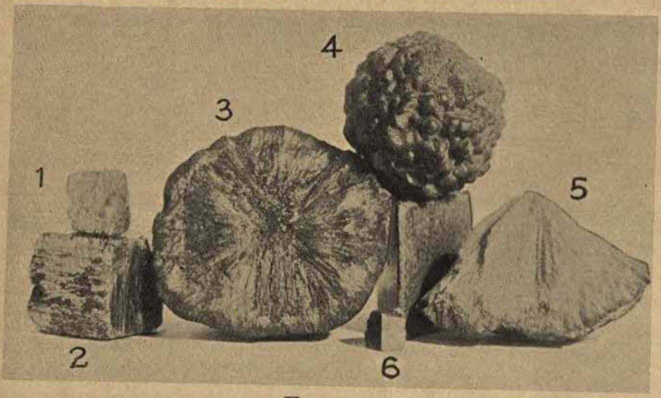


FIG. 34

3, 4, *and* 5. *Nodules of Iron Pyrites.* 2. *Cubic Crystal of Pyrites.* 1 *and* 6. *Galena*

Ores

Most metals, except gold, are found in a combined state, as oxides, carbonates, sulphides, etc., and have to be separated before being used. Many of the ores are found in veins, or lodes, in rocks which have been cracked or faulted. Hot liquids and gases from the interior have been forced into these cracks and deposited quartz crystals or fluor spar crystals, together with more valuable metallic ores, such as tinstone, galena, zinc blende, copper pyrites, etc. The chief ore of lead, a mineral of silvery metallic appearance, is known as galena (sulphide of lead). Galena was commonly used for wireless crystals. Copper pyrites (copper sulphide) is somewhat similar to iron pyrites in appearance, but it is soft and can be scratched with a knife.

Silver sulphide is often found with galena, and may be readily extracted from it.

Zinc blende is a sulphide of zinc which is sometimes mistaken for galena. It is, however, browner, more readily cleaved, less lustrous, and not so hard. Tin stone is an oxide of tin brownish-black in colour and very heavy. Tin ore, like gold, is often obtained from river deposits and gravels, because, being heavy, it is not readily washed away to sea.

The search for gold, silver, and other useful minerals has often led to the opening of new districts in undeveloped parts of the world.

Soils

Soils have been formed by the weathering of rocks. As there are many kinds of rocks so there must be many types of soil formed from them. Besides containing fragments of rocks, soils also contain humus from decaying animal and vegetable matter. The fertility of soil depends upon many factors—

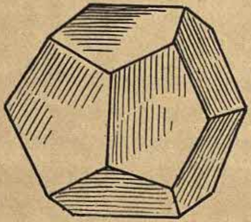


FIG. 35

Iron Pyrites Crystal

1. The amount of available food material for plants. This depends not only upon the chemical composition, but also upon the solubility

of the compounds. Food material may be present but unavailable because insoluble.

2. Depth of soil. Shallow soils suffer from drought.

3. Porosity of soil and subsoil. If very porous the soil may be affected by drought. If impermeable it may be waterlogged and plants would suffer from lack of air in the soil.

4. Temperature. Dark soils are warmer than light-coloured ones. Wet soils colder than dry ones. Soils on slopes facing south are the warmest.

Types of Soil

The three main types of soil are sandy soils, clay soils, and limestone soils, but there are many intermediate types because soil is not formed only from pure rocks, nor does it always remain in the place where it was formed. Drift soils which have been removed from the place of origin by rivers, glaciers, or winds may be of a very mixed character. E.g. alluvial soils of river flood plains and deltas, loess, soils formed from boulder clay, and other glacial deposits, etc.

SANDY SOILS. Sandy soil may contain very little food material and suffer from drought. Many districts of Britain covered with heather, bracken, bramble, and forest have such sandy soils. E.g. parts of Surrey, Berkshire, Hampshire, Highlands of Scotland. Impure clayey sands may be very fertile, however.

CLAY SOILS. Lowlying, undrained, clay soils may be marshy or at least very cold, but if clay soil be well drained, either naturally or artificially, it often forms good, deep, drought-resisting soil suitable for cattle pastures or for the growth of wheat and root crops. Bad clay soils are improved by drainage and the addition of sand or lime. Lime acts chemically by forming soluble compounds from the clays, thus unlocking some of the food material which was present in an unavailable form.

CHALK OR LIMESTONE SOILS. Soils on chalk and limestone hills are often shallow and lacking n lime (!). They consist largely of the insoluble esidues of the rock from which they were erived. Such soils are suitable for sheep astures as the grass is short and the ground ot too moist. E.g. Cotswolds, Chilterns, Cheviots, South Downs, and Wolds are noted for sheep rearing.

OTHER SOILS. As limestones, sandstones, and clays are not always naturally pure, so we may find clayey limestones, sandy clays, and clayey sands which form soils with varying properties. Such soils as loams—a mixture of sand and clay—and marls—a mixture of clay and limestone—form the fertile agricultural parts of Central England.

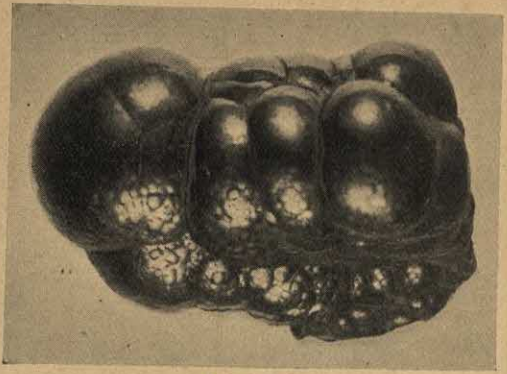


FIG. 36

Haematite—Kidney Iron Ore

Practical work may consist of examinations of local soils to determine roughly the proportion of humus, sand, clay, and limestone. Any soils seen on walks should be noticed and the type of vegetation studied. Add lime to damp clayey soil and note how the clay becomes more easily broken up. Test the amount of soluble matter.

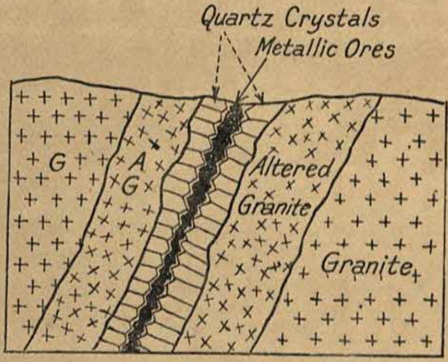
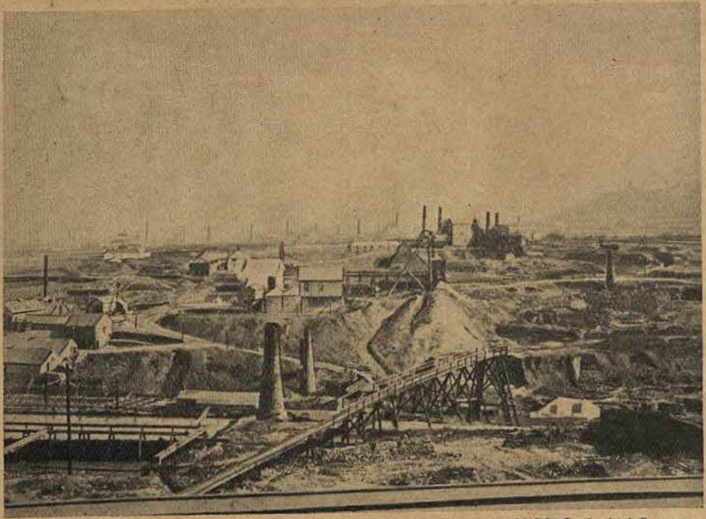


FIG. 37

A Mineral Lode or Vein in Granite

Water Supply

The water supply of a district depends upon the rainfall, the kind of rock upon which it falls, and on the way in which the strata are arranged.



By courtesy of H.M. Geological Survey

FIG. 38

General View of Mining District, Cornwall

Clays throw off most of the water as surface drainage, but most other rocks allow water to percolate through pores and cracks. About 50 per cent of the rain which falls usually sinks into the crust until it reaches some impervious strata. In the porous strata it accumulates in pores and cracks, forming a water-table. Much of this water reappears as springs under circumstances such as shown in Figs. 40 and 41 Still more of this water may be obtained by sinking wells either ordinary or artesian (Figs 20 and 42).

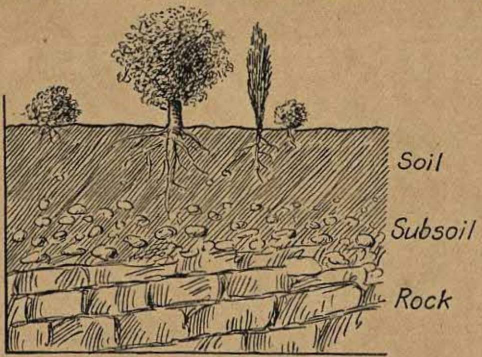


FIG. 39

Formation of Soil from Rocks

The influence of rocks upon water supply i illustrated by Fig. 43. Th original villages were built wher water could be obtained from th porous chalk. (See also Fig. 19.) Water from shallow springs and wells situated near big towns is often unfit to use for drinking purposes. London obtains its water from the rivers Thames and Lea and from artesian wells. Manchester, Liverpool, and other towns in industrial districts cannot use the foul water in their local rivers, but obtain their supplies from mountain districts E.g. Liverpool from Lake Vyrnwy Manchester from Thirlmere, etc. The supply of water to large towns, many of which use from 30–100 gal. per person per day costs much money for pumping purification, building of dams and reservoirs, and laying of pipes. There is therefore need to exercise reasonable care so tha water is not unnecessarily wasted.

Further work might include: Methods o filtration, purification, and softening—use o water for irrigation—Assouan dam, etc.—wate power for electrical works, e.g. Canada, Switz land, Scandinavia—drainage of marshy land a clay lands—prevention of disease by keepi natural waters free from impurities—care to exercised by local authorities that rubb should not be tipped in old quarries made porous strata—consultation of geologists bef spending money on wells or mines.

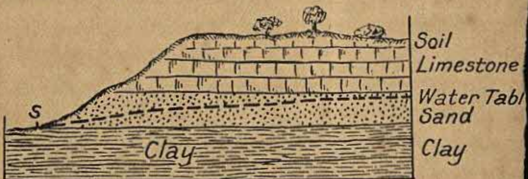


FIG. 40

Porous Strata above Clay (Spring at S)

Fossils

Fossils are the remains of plants or animals preserved in the rocks. Except under rare circumstances, only the hard parts are preserved, the soft material being subject to rapid decay.

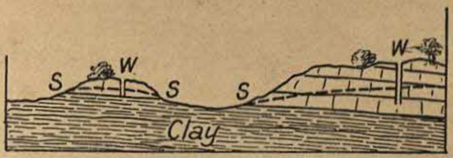


FIG. 41

Spring Formation

S = Springs. W = Well
Dotted line = Water table.

Types of Things Found Fossil

1. Bones, teeth, tusks, scales and armour plate of fish, amphibians, reptiles, and mammals.

2. Shells of molluscs, sea-urchins, crustacea, foraminiferae, etc.

3. Skeletons of corals, sponges, bryozoa, etc.

4. Leaves, stems, roots, cones, spores, and seeds of plants.

5. Moulds, or casts, and impressions of things preserved for a time and destroyed after the mould or impression has been formed.

6. More rarely. Insects and their vings, feathers, skin, and hair.

7. Some people include worm casts nd trails, footprints of birds and nimals, and even rain pittings and ipplemarks.

Note 1. Remains of birds and land reatures will only rarely be pre-rved; the most common fossils eing remains of sea creatures, especi-ly shells and corals.

Note 2. The records of creatures d plants which have lived is neces-rily incomplete, since some may never have en preserved and others that were, may not ve been discovered.

Uses of Fossils

By a study of fossils and their distribution in the rocks we learn—

1. Of the ancient distribution of land and water.

2. Of the climate of different periods, e.g. corals live in warm seas.

3. Whether the deposits were made in fresh or salt water; whether in deep water or near the shore.

4. Of the changes in the flora and fauna throughout geological time.

5. Of the gradual rise and decline in importance of certain classes of animals and plants, e.g. trilobites, ammonites, reptiles.

6. To distinguish one set of rocks from another similar set, and to trace rocks made during the same periods in different places. It is important to be able to tell, from the layers of rock visible, what rocks may, or may not, be present below

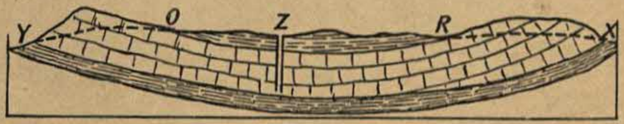


FIG. 42

London Basin

Springs at X and Y. Intermittent springs and bournes at R and O. Artesian well at Z.

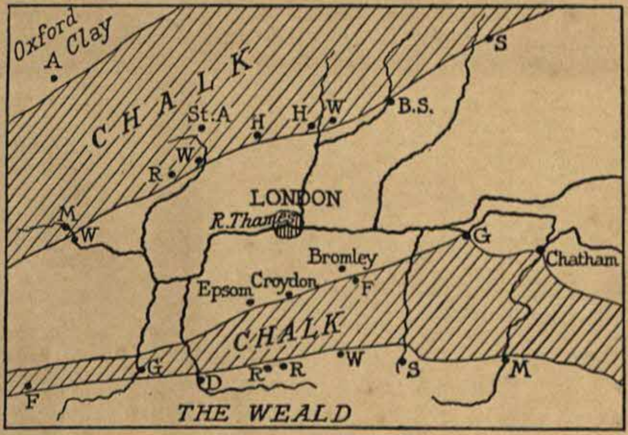


FIG. 43

Towns Situated along the Outcrop of the Chalk because of the Springs

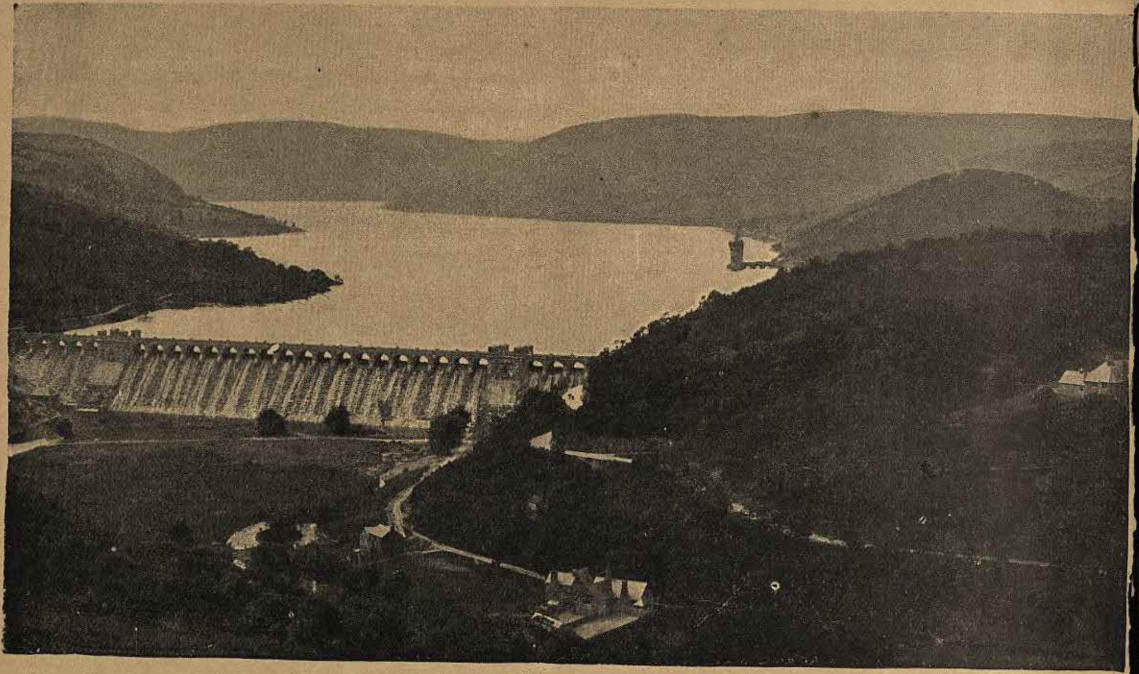
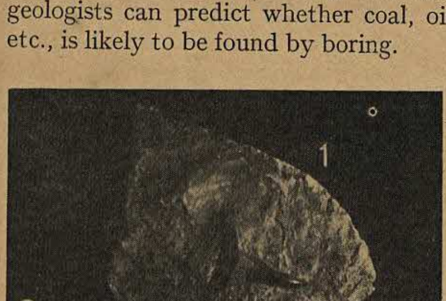


FIG. 44
Lake Vyrnwy

or above them. By using this knowledge, geologists can predict whether coal, oil, water, etc., is likely to be found by boring.

The oldest rocks (palaeozoic) contain trilobites, crinoids, graptolites, corals, fish, etc. The next lot of rocks (mesozoic) contain many



H. E. Taylor

FIG. 45
Fossils

1. *Shark's tooth in limestone.*
2. *Shark's teeth from London Clay, Herne Bay.*
3. *A vertebra from Gault Clay.*

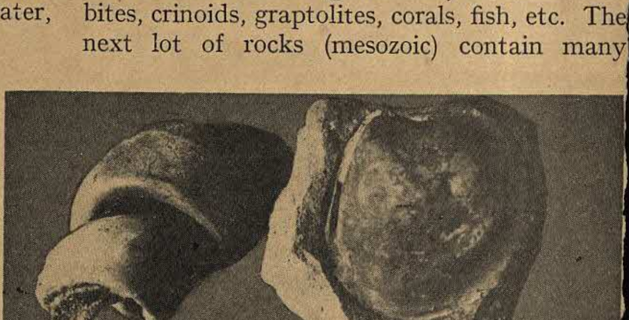


FIG. 46
Casts of Fossils

ammonites, belemnites, brachiopods, corals, molluscs, and reptiles.

The cainozoic rocks contain no trilobites, graptolites, ammonites, etc., and shells of molluscs are more like those found at the present day. In these rocks mammals become more important although not commonly found by amateurs.

Only in the very latest rocks are remains of man found.

"The Story of the Rocks" Chart

Some attempt should be made to explain the names on geological maps used to indicate the various rocks and their ages. In the PRACTICAL SENIOR TEACHER CHART, the same names have been used to indicate both the formations and periods. A comparison with such phrases as Norman architecture, Victorian furniture, etc., will show that Devonian rocks are not only found in Devon, nor Cambrian rocks only in Wales, but in many other parts also. A Devonian rock is a rock made during the same period as those which were called Devonian when first studied in Devon. It may be sandstone, limestone, or shale, or even volcanic material if formed during that period.

The rocks of the crust have been divided into five great groups formed in five eras: Archaean, Palaeozoic, Mesozoic, Cainozoic, Quaternary. Sometimes Archaean and Palaeozoic are called Primary, Mesozoic Secondary, and Cainozoic Tertiary. Each of the eras may be likened to a period in history such as Roman Period, etc.; and as such periods are divided into reigns, so eras are divided into periods, such as Devonian, Carboniferous, etc. The systems of rocks formed in these periods may be still further divided nto divisions and zones. Zones and divisions re distinguished by small assemblages of fossils, ystems by larger assemblages, and groups by till larger ones. Fossils characteristic of the Palaeozoic often die out by Mesozoic times, and hose of the Mesozoic by Cainozoic times. On he other hand, new types of creatures were volved as time went on.

A study of the chart shows that reptiles were mportant in Mesozoic times, mammals became mportant in Cainozoic, and man in Quaternary times. The chart also indicates when certain mountains were uplifted when the coal was formed, and when the Great Glacial Period occurred. Coal is found in the coal measures of the Carboniferous system of Palaeozoic rocks, which were formed in the Carboniferous Period of the Palaeozoic Era.

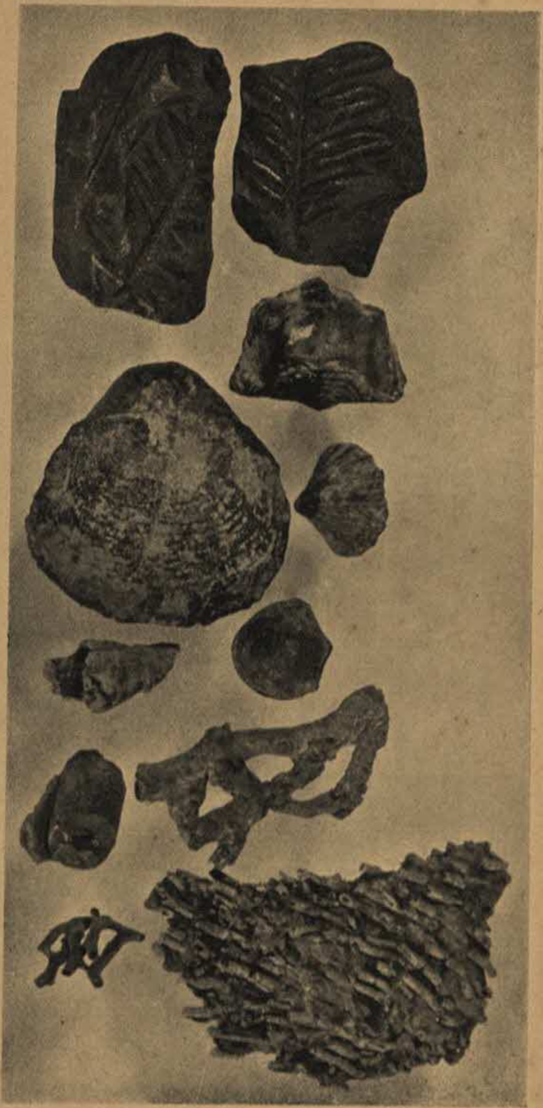


FIG. 47
Palaeozoic Fossils

As historians do not usually notice days and hours, so geologists do not use centuries or years to measure time. In order to give some idea of geological time, the approximate number of years since several important geological epochs has been shown in the table; but it is better to think in terms of periods rather than millions of years.

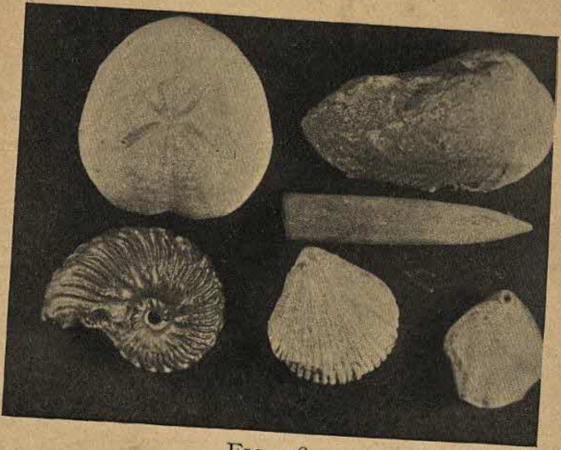


FIG. 48
Mesozoic Fossils

VI. Important Points for the Teacher

1. Stress the TIME element.
2. Extremely slow action of nature's tools and of earth movements.
3. Comparatively rapid way man is using up mineral resources and assisting nature in altering the surface features by mining and quarrying.
4. The influence of rocks upon industry, water supply, and agriculture, and therefore upon distribution of populations.
5. The diversity of rocks and soils.
6. Examine geological maps.
7. Examine collections of specimens.

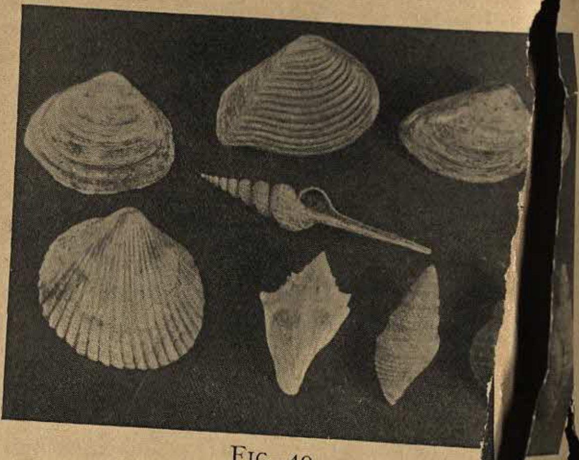


FIG. 49
Some Cainozoic Fossils

8. Show pictures, slides, and sections to i trate lessons. (Good slides or photographs obtainable from the Geological Survey, Exl tion Road, South Kensington, London).
9. Perform simple experiments in crystal tion, solution, action of acids on rocks, hardr and friability, etc.
10. Alter the scheme to suit local condition

BOOKS RECOMMENDED

For Class or Library. Wonders of the Earth Crust, by H. E. Taylor (Pitman, 2s. 6d.)

For Teacher's Reference. Geology for Beginner W. W. Watts (Macmillan & Co.).

HYGIENE

(For the sake of convenience, the teacher is referred to as "he" and "him." This is merely for simplicity, and, unless the sexes are named, the following is applicable to both men and women teachers, and both boys and girls.)

General Principles

MOST teachers, immersed in time-table details, come to divide their work into "subjects." There is danger, in both Senior and Central Schools, of allowing specialization to intensify this error. Moral, physical, and health education must never be bounded by the limits set for a "subject." A belief in the physical basis of life and education is the chief tenet of every educationist, but it is more often heard on the platform than demonstrated in schools or colleges. Physical education, in its widest sense, must embrace the whole of a child's activities, and the "wholeness" of life must be preserved throughout his education. For convenience of examination we divide life into moral, physical, and mental, but life itself is one whole and cannot be divided, however much we pretend to do so. What, then, is the place of Health Education? Like discipline and behaviour, it must permeate the life of the school, and must govern the time-table—as it generally does vaguely—and not be subservient to it. Senior scholars need more definite instruction in principles, which they will more completely appreciate and understand, than Juniors. Health practice needs just as much care as ever. "Science" applied to the body has already fulfilled its dual use—which much of the science taught never does.

It is, however, necessary to give young adolescents a simple but sound body of knowledge for their guidance through life. Let there be no mistake: this duty has been steadily neglected in the past. What has been given has consisted largely of a disconnected list of names. Let us be less ambitious over the ground we cover, but see that it is well surveyed.

Health, as we are about to discuss it, does not mean merely the absence of disease. It means the unification or integration of the whole. It is positive. Whatever the meaning of happiness, health is part of it; and during childhood and youth, at least, health must mean a glow, a boundless endeavour of hope, a definite feeling of ability to perform and to enjoy, and the desire to do so. It means other things too, but, unless we reach that almost unconscious uplifting of body and spirit, we are merely living. It is the aim of education to enable us to live well. But this does not mean a preoccupation with health; that in itself means a partial disintegration. Health or well-being must exist as a thing taken for granted—let this be a constant thought with the teacher.

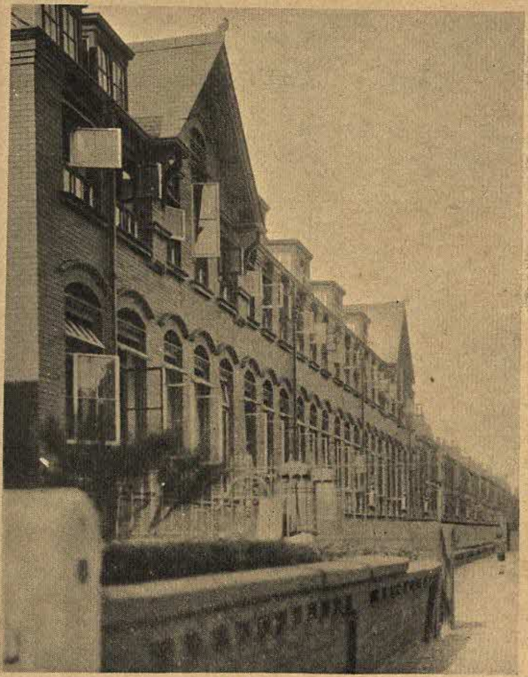


FIG. 1

Open Windows

A Senior School on an ordinary school day, photographed unknown to the staff.

HYGIENE PRACTICE

Scope

The teacher has little interest in a textbook that discusses school sites, drains, and the like. He has no control over them. But whatever phase of a child's behaviour a teacher may influence for the good of that child's health comes within the limits of school hygiene practice—and not only the health of the child but that of the teacher. All a teacher really receives are the bodies of the children. He may, and does, draw intelligent conclusions concerning their minds and souls, but these are all based on bodily manifestations. He must, then, for his professional integrity, realize the state of these bodily media, and do all in his power to make them able, flexible, and powerful. Too often those who are blessed with bodily ability, in its widest sense, realize least how much of their mental and spiritual freedom they owe to it. So that the cry "keep fit" is not merely a slogan, a parrot cry, to a teacher. He is one of the few persons who should be able to answer the question "Fit?—for what?" The answer is never complete; for it includes the wholeness of life, a wholeness no teacher may ever forget.

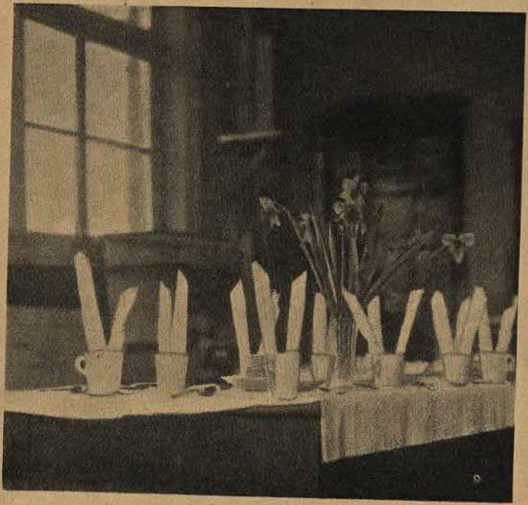


FIG. 2

Table Set for "Free Meals"—as Set Daily

Nutrition

Health, at the poorest estimate, in childhood depends largely on sufficient suitable food, the provision of which, although evidently a parental duty, does sometimes come within the teacher's influence. This is discussed in the next paragraph. Eating habits themselves have a great influence on the effects of food upon the body, and, although attention should have been directed to these at an earlier age, it is in the Senior and Central school that children, particularly boys, attempt to throw off many of the habits of earlier years. Where there are any school meals the following cannot be disregarded—

1. Washing before a meal should be invariable.
2. The table must be properly set with decent drinking vessels (one each), clean table covering, and paper napkins.
3. Eat silently with lips closed, do not FILL the mouth, eat slowly, chew thoroughly and empty the mouth before refilling, drink only after emptying the mouth, use cutlery neatly, use one drinking vessel—your own. These are home habits, we know. If they have been practised well, the teacher is relieved from inaugurating them. If not, they are part of his hygienic duty.
4. Encourage a chatty meal, and the ordinary courtesies of the table. They make for leisurely eating and better health.
5. School meals are better than sandwiches. They will probably have well-arranged menus, and will discourage a faddiness that often develops at home.
6. Encourage flowers, etc. To deny the beneficial effect of such things is to condemn all appointments of the table, beyond the roughest, as meaningless, useless, and pretentious, which is absurd.
7. All must rise from the table together. Say grace. This prevents hurrying off to games, a practice which should be forbidden before the lapse of a certain interval—for obvious reasons. Netball and football games are often started three or four minutes after the end of a hurried midday meal.
8. Attitudes at table may need correction.

These seem commonplace. They are. So are most health habits. Corrections are best administered in private, and with kindly tact, especially where it is suspected that home usages do not provide the necessary training. The establishment of a decent school table usage will provide the best corrective.

BADLY NOURISHED CHILDREN

It has been established that the authority that demands attendance at school must also see that the children are in a fit physical condition to benefit by the education offered there. Among Senior scholars, the effects of bad nourishment probably have a history, but some cases there are that only a sharp-eyed teacher can discover. Under present conditions in schools these should be attended to immediately, and the *liaison* between the school and clinic should be smooth and swift. The interested teacher will, almost certainly, know of special home conditions, but, even if not, the following will help.

The usual signs of faulty nourishment are: flabbiness generally, rickets, deficient weight for height (cf. local average table), muddy or sallow complexion, dullness of the eyes, lack of lustre of the hair, and certain signs not wholly physical, such as: a loss of concentration, restlessness, apathy, or dejection. The presence of all symptoms simultaneously is unlikely. They are detailed merely as a guide.

But, although the final word as to the provision of meals lies with the S.M.O., the treatment does not. It lies partially with the teacher, who must see that such children are relieved from pressure; homework should be lightened and every effort made to help them over a difficult time. Very often voluntary help is given from school funds. Mid-morning milk is a common form, paid for by most recipients, but tactfully supplied to those who cannot afford to pay. After all, one must realize that the teaching profession is the most widely extended health organization in the country, and much of the work is splendidly voluntary; nevertheless one is constrained to ask teachers to see that their efforts are not misdirected.

See that the morning drink is milk, if it is possible, not a substitute. It should be drunk slowly. Some schools even provide straws to ensure this. The haste and possible carelessness in preparation are great objections to morning "snacks," which are often taken standing. The pressure of academic instruction makes this haste almost inevitable, but how foolish! It is more important fundamentally that a child should be well fed than that a laudable but useless attempt be made to teach him, ill-fed.

FOOD—MISCELLANEOUS HINTS

Do not discourage frequent water drinking. The body, two-thirds of which is water, requires a comparatively large amount. Take care immediately after violent exertion, and in hot weather. The children's immediate requirements can, as a rule, be met by a mouth wash first, after which water may be taken slowly. It is with regret that the writer finds that drinking vessels present a problem unsolved except in the obvious way. They should be frequently scalded and scoured, as they spread diphtheria, etc. Probably the upward jet is best, since it requires no drinking vessels; there are objections to it, however.

Irregular eating between meals and any kind of chewing should not be tolerated in schools. Sweets of a reasonable quality there is no objection to—on the contrary—but let them be eaten immediately after a meal, of which they then form a part, as it were.

Refinements of all kinds, in connection with food habits, tend to have good derivative effects, which are good as long as they remain derivative—affectations, masquerading as refinements, are still affectations, and vulgar.

Keep a good look-out during cold weather. Children need more food then.

Food kept on the school premises must be in a cool, well-ventilated, well-lighted place that is clean and free from dust. Milk containers should be regularly scalded and covered with frequently washed muslin.

Avoid midday detentions. They make irregular meal times for children and staff, and misunderstandings between staff and parents. Some schools apply this advice to the afternoon session, ringing a bell, a certain time after dismissal, to clear all premises. This is obviously reasonable with Senior children, to whom home tasks are given, and, especially during "summer time," has a direct effect upon the number of hours of sleep a child may get. Of course, such a rule (to clear the premises) could well be relaxed on occasion.

(For Foods and Food Values see "Dietetics," p. 282.)

Fresh Air and Ventilation

How glibly we talk of fresh air! But do all realize that foul and impure air is as bad as adulterated food, against which a whole battery of Acts is aimed? Open-air schools and the enlargement of physical training indicate the march of our practice, but schools with gymnasia need a constant reminder that apparatus and a good floor do not compensate for a lack of fresh air. The real fault lies in an absence of routine, for most people become accustomed to an atmosphere that gradually becomes foul, especially when they are interested in their work; and one must not delay ventilation on a cold day until the air feels foul. It is known that a closed classroom becomes stale and its air impure. It ought to be ventilated as a matter of routine.

Ventilation systems are generally something more or less fixed, but in the great majority of cases windows are movable. Do not be afraid of the usual definition of a draught (air moving faster than 3 ft. per second or that is changed in a room oftener than three times an hour). At all events, it does give a certain amount of margin to begin with. Keep the room thermometer somewhere near 58° F. Flush the room regularly during a session—in most Senior or Central Schools this ought to be automatic, at least at the change of lesson, and must be thorough. Moving air is not so stuffy as still air. If the weather be very cold, and constantly opened windows make the temperature approximate to that of the open, stop teaching while doors and windows are opened wide, and give a short burst of properly carried out exercises, including leg, arm, and trunk.

It is very important to establish an open window habit that can be transferred from school to home. The aim is to prevent stagnation of the air, and this can be illustrated by placing lighted candles in various parts of the classroom at various heights. The movement—or lack of it—of the flames shows clearly whether there is movement of the air. Stagnation and moisture are the greatest faults.

Breathing

Volumes have been written on this topic alone. During the physical training lesson, care must be taken to give plain advice about the manner of voluntary aid to breathing, and the resultant establishment of a good breathing habit. Slack teaching has often produced a bad habit of using only the upper part of the chest, especially in the case of girls and women. The normal method of involuntary quiet breathing is diaphragmatic, and this should be developed to a great range by the use of voluntary muscles; to this should be added a flexible use of the chest muscles, so that the full capacity of the lungs is brought into play at will. S.M.O.'s notice the lack of this ability. Attempts at deep breathing, i.e. assisting quiet involuntary breathing by means of voluntary muscles, are often grotesque among children who have not mastered the necessary localization of effort. It is worth taking a little extra care with faulty breathers. A supine position is best for instruction. Never allow the shoulders to lift, nor the chest to be fixed with rigidity.

Senior scholars ought to have reached the stage of control at which they can consciously extend the range of diaphragm or chest. Remember that breathing control for singing or elocution is an advance on straightforward deep breathing, and involves finer control of the breathing mechanism. It is unfortunate that breathing control exercises for singing are often taught before a child has mastered the ordinary breathing mechanism for flexibility and capacity, with the result that rigidity and bad localization of effort become habits, because of ignorance of how such effort should be applied. Never give breathing exercises in any atmosphere but the best available, which is of course as a rule found outside.

Clothing

Except the very poor, many children wear too many layers: ten and eleven have come to the writer's notice. This is absurd for the coldest English weather. To improve this the parents' co-operation is essential, and alteration should probably be gradual. Once a term, the needlework mistress should exhibit a specimen outfit for that season, and if possible put it on a suitable scholar. See that the air has access to skin surfaces, but do not go to extremes. We are concerned with health and not with fashion, and that which left almost the whole of the thigh surface exposed, almost throughout the year, was of doubtful value, as the area mentioned is too large a proportion of the whole, and in some cases the exposure was harmful. Bare legs are excellent in all but the coldest weather, and this habit is well begun in physical training lessons in warm weather (see Fig. 4).

(*a*) GIRLS

Exercise can well be taken—and often is—without a tunic and without stockings. Under-garments will be of various forms, but dress should approximate to: vest (thin wool), knickers (easily washable); cotton frock or tunic (washable) for summer, with a slight addition for cool days. In winter a thicker vest and knickers, or combinations and knickers, frock or tunic, and socks or stockings; the knickers must not be excessively short. If tunics are removed a jersey is good; if not, a blouse. Even in selective schools where the health average may be high, it is often impossible to assess at once any damage done by excessive exposure. The effects may lie dormant. Even among adults, it is doubtful whether the greater degree of exposure, practised by girls and women of late years, has had the beneficial effects that writers in the cheap press would have us believe. It is only one factor, and a doubtful one.

Dark blue knickers and tunics tend to become dirtier than lighter coloured garments would be allowed to.

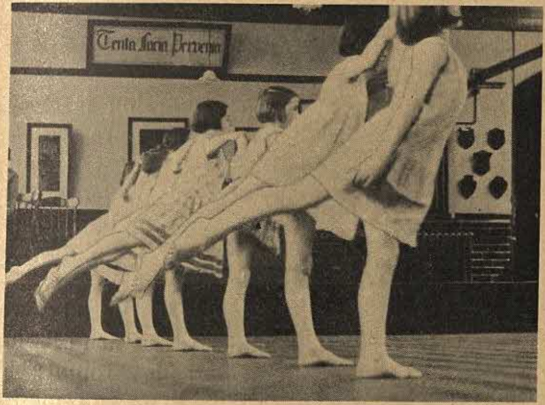


FIG. 3

Exercises for Flexibility

These exercises are performed in bare feet and very thin tunics.

Thin washable linings for knickers are useful, but they add an unnecessary layer for any but cold weather. Give instructions for the cleansing of dark tunics and knickers; and have them done in the domestic centre if possible.

(*b*) BOYS

It is good to see boys discarding collars, and wearing open-necked shirts. Their dress should approximate to that of the girls; but, unfortunately, the standard "suit" prevents this to some extent, and tends to send them back to collars, and, often, too many underlayers. These latter are difficult to reduce, but it should be attempted as with girls. Belts are often preferred to braces, but they ought not to be tight; and it is safest to have the buckles at the side. Braces should rest as near to the neck as possible, away from the points of the shoulders. Supervision of neatness, cleanliness, and suitability of dress is part of physical and hygienic education.

Clothing at Special Times

The appearance of a school dress is not the only criterion that should govern its selection. Physical Training and Games periods are more insistent in their demands for a suitable dress than any other, since there is often no time to change, but merely to adapt. The boy should take off as much as possible and roll up his sleeves, putting on flexible shoes. The girls who doff tunics are increasing in numbers (see Fig. 4). Knickers and a thin jersey make an excellent costume. It should be noted that, with young children, the constant wearing of heel-less rubber shoes may produce a tendency to flat-foot. On the other hand, the practice of doing preliminary exercises for dancing in bare feet has been tried among older girls, with a great gain in flexibility in toes and ankles, and a greater general freedom of movement, which has been transferred to the dramatic work, to the advantage of plays and players (see Fig. 3).

Changing for games ought to be a more frequent practice than it is in Senior and Central Schools. The condition of underclothing, after vigorous games played in ordinary clothes, must be very bad; and colds are often the result. At least, one can encourage children to bring their own towels, and rub down after games. Cold sponge baths cost next to nothing. This should be the minimum for boys, and ought to become so for girls. With a start like this, you establish the fact that cleanliness of this kind is as necessary for these children as for those who are sent to secondary schools—there is little difference in the ages of the majority.

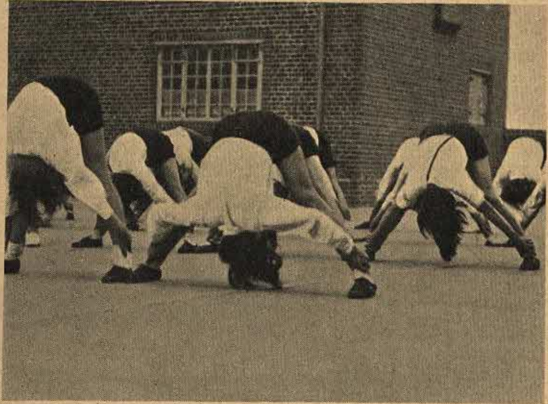


FIG. 4

A Sensible Costume for Physical Training and Games

This is worn by these girls whenever they have the opportunity.

Washing and Bathing

The absurd custom of providing only cold water for washing in schools still continues. It is impossible to wash clean, especially in cold weather, in cold water, and, wherever possible, the children should be encouraged to use hot water for washing—not only hands and face, but the whole body. One hot bath a week should be the absolute minimum; and more frequent baths should be encouraged. The skin is one of the organs by which we get rid of waste matter; in fact, the extreme outer layers of the skin are waste matter, and, unless this is removed by regular washing and rubbing, this organ cannot function adequately. Of course, it is difficult for the teacher to do much in this respect, but there should be no neglect on the part of the children for lack of knowledge. This the teacher can, and should, give. There is widespread ignorance on this matter of bathing. Cold water has a decided tonic effect upon the body generally, but, like all tonics, should be used with reasonable care. The immediate effect of cold water is to cause the superficial blood-vessels to contract, and this forces the blood towards the centre. Then comes the reaction, when the blood is pumped to the surface, to raise the surface temperature. In those cases, however, where this reaction is much delayed or is non-existent, cold baths, especially a cold plunge, must be used with discretion, and the subsequent rubbing must be vigorous, in order to help the reaction, the presence of which is, in practically all cases, indicated by a glowing skin. Evidence of the lack of it is seen in blue extremities. A short cold shower is probably best for children, and can have admirable tonic effect when it follows a hot bath, which latter leaves the pores open. If the foregoing suggestion, in the case of those with poor circulation and reaction, be followed, a teacher should place emphasis upon the bracing effect of cold water, especially when talking of the cleansing properties of hot.

Since healthy children get dirty during their countless activities, it is necessary that it be pointed out that the one or two baths a week be considered a minimum, and that dirt must be removed frequently. There is a great deal of difference between a dirtied collar and a dirty one; and, in the same way, there is a similar difference between a dirtied child and a dirty one. Many opportunities for knowing the children in this respect are to be found during physical training lessons, games lessons and after, and especially swimming lessons. So long as the normal condition of the body is a clean one, it does not matter how dirty it gets occasionally—this is always a comforting idea to a vigorous healthy child at school.

Swimming

The technical aspect of swimming is dealt with under that heading, but there are certain hygienic principles to be observed: most of them well known, but equally well neglected. The effect of a weekly visit to a swimming bath upon the cleanliness of most children has been noticed by most teachers. Raise the standard.

Insist on *every* pupil's having a footbath before entering the pool. The object is to wash off the dust gathered in the roads and playground; it also gives a chance to the slack ones to remedy a dirty condition. If general cleanliness does not improve, have a parade before the footbath, and send the cleanest ones in to swim first. Of course, no child should enter the water with any skin or ear disease, or with infection of any kind.

See that costumes are wrung out into the gutter, and not into the pool, and that all parts of the body, especially hair if it has got wet, are thoroughly dried. A cabin for each child should be the rule, of course. A short shower at the end of a lesson makes an excellent cleanly finish.

The excitement attendant on going to swimming is so great among some children that the ordinary dictates of commonsense are often forgotten, with the result that a hurried midday meal is often followed by a dash to the baths —when the digestive organs are to be allowed to function in peace, goodness knows! The duration of a swimming period should be watched, and shortened for those who show that they cannot comfortably stand the usual twenty minutes in the water. Of course, the first two or three lessons may well be shorter than this. Discourage eating in cabins; and see that all are properly clothed before going out of the warm bath's building into cold air.

Hair

Any writer on hygiene must heave a sigh of relief that there is no longer need to write at length on the cleanliness of the head. In Senior Schools, cases that need attention are comparatively few, and should be referred to the school clinic at once. Short hair is much more healthy than long, and, it is hoped, will continue to be the custom. Adequate cloakroom accommodation is essential, so that caps and hats may be kept quite separate, and monitors or prefects should see that it is used. A pride in the appearance of the hair often means a more regular brushing and cleansing of the scalp. Encourage it. Give demonstrations of the cleansing of hair brushes and combs; and remember that, in spite of our lofty contempt for a dirty person, a great deal of expense or effort is necessary to keep one's person and clothing regularly clean. Every hint then, even of the most commonplace kind, that will help to make cleanliness easier or more interesting should be given. That it is the commonplaceness of these things that is the cause of their omission, one feels sure; and the school should be a more reliable source of information than the columns of the cheap press.

Waste

One of the most cogent reasons for the teaching of those principles of hygiene that are set forth in later pages is that it enables a teacher to talk, in a matter-of-fact and scientific way, of functions of the body, mention of which older children avoid, from discomfort or sheer fright. The elimination of waste matter is among these, and all allusions to it should be referred to the lessons dealing with the organs concerned. As soon as sane relations are established with a class, direct references to keeping the food tubes clean can be made. A useful visit may be made to the furnace chamber of the heating system of the school, when it may be shown with what care "fires are raked," and the obvious analogy made. A regular habit of "raking fires" each morning, at the very least, by clearing the bowels, cannot be established too early, but it is never too late to begin. Positive health is impossible without it; and although references to pathological conditions, resulting from a neglect of the habit, ought not to be the method used with children (nor with adults), yet the teacher must realize that an enormous amount of discomfort and disease results from irregularity in the discharge of this function.

The elimination of liquid waste from the bladder is a function that varies among school children, and although control of it has, by this age, been established, there must be no tendency on the part of the teacher to be unwilling to allow a child to attend to this function, immediately on request. He may take the opportunity to improve the occasion, but it must take no other form but advice. The whole of this section is difficult, so far as direct relations between pupil and teacher are concerned, but there is not the slightest real reason for the absolute avoidance of the subject that often obtains. There need be no awkwardness, even with older children, in the handling of the matter, if the thing is attacked as boldly as is required by the very nature of this phase of health habits. It should go without saying that the appointments of outside offices should be as clean and as convenient as is possible. Sanitary paper must be available and used.

One other organ of elimination, the skin, has already been dealt with under Bathing. The lungs are discussed later.

Postures

One of the most astonishing, and at the same time the most satisfactory, developments noticed by the writer in his work is the interest taken by parents in the correction of faulty postures, once these have been patiently shown and explained to them. In fact, the direct effect on particular parts of the body of exercises designed for them, and a clear exposition of the faults to be removed have been the means of "converting" certain head teachers to a realization of the general usefulness of physical training. The Central and Senior School is the place of origin of many faulty postures; and the teacher of Geography, or Mathematics, or any other subject must be brought to realize that posture is as much his job as anybody's. The bony structure of the body is arranged in such a way as to allow the organs of the body to function healthily, i.e. to allow food to be assimilated properly, the waste eliminated, growth to proceed normally, tissues to be repaired adequately, and breathing to be free and unimpaired. Any departure from a good posture will certainly affect one or more of these, and should be corrected before it has time to become habitual. Anything beyond the care of the teacher should be reported to the S.M.O. Most of the postural faults to be found in a school depend upon the carriage of the head, the flexibility of the shoulder girdle, and the curves of the spine.

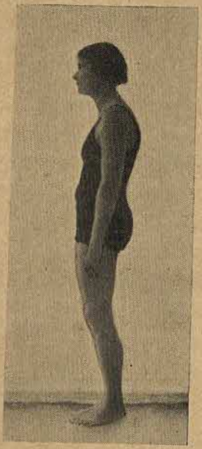


FIG. 6
Fatigue Position

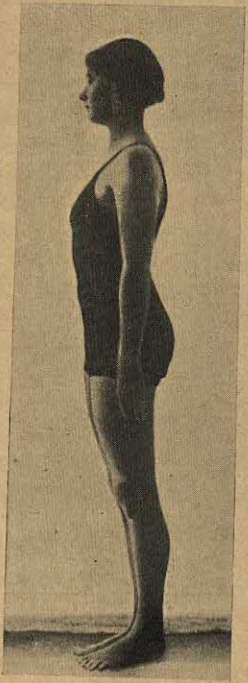


FIG. 5
Upright Posture

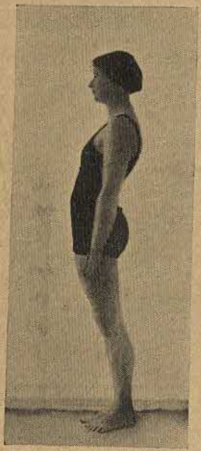


FIG. 7
Fatigue Position

Figs. 6 *and* 7 *fatigue positions that tend to become habitual and fixed, if not counteracted.*

Flat foot has already been referred to. It is no part of a teacher's work, normally, to do more than prevent the occurrence of postural faults; nor does an extensive treatment of them come into a discussion of hygienic habits, except in so much as common school or home postures are likely to produce faults (see photographs).

Seating

Many schools are provided with seat and desk combined. Not much can be done in these cases, unless the furniture is adjustable. At least, the teacher can see that each child is provided with the seat that is reasonably suitable to his stature and build. This is mentioned because its neglect is as common as its observance. Fig. 14 shows the different arrangements of these fixed benches. Obviously the minus desk is the best, and in modern times is commonest. The old plus atrocities are happily becoming things of the past. Where, however, the education authority has been sufficiently well advised to provide chairs and tables, the teacher can exercise a valuable supervision over their use. A chair is movable—see that it is placed correctly in relation to the table. It is an easy matter to exchange between rooms if necessary. Do so. A good plan is to have all chairs in a school numbered consecutively, either on the backs or on the seats. The resultant convenience is obvious.

The whole of our practice in habit forming

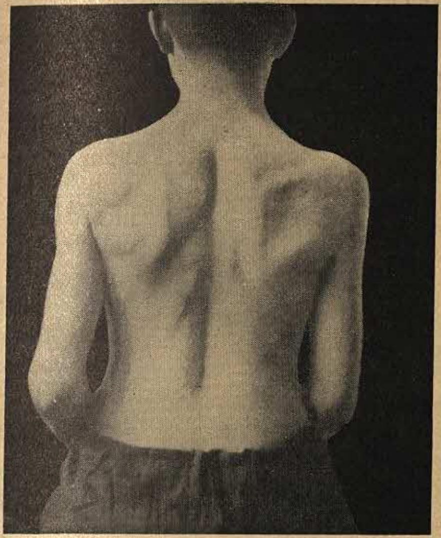
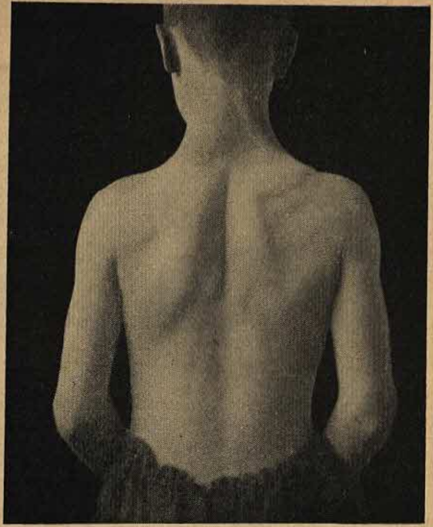


FIG. 8
Two of the most athletic boys in a large Central School sitting normally

These two boys were photographed as below without any "posing"



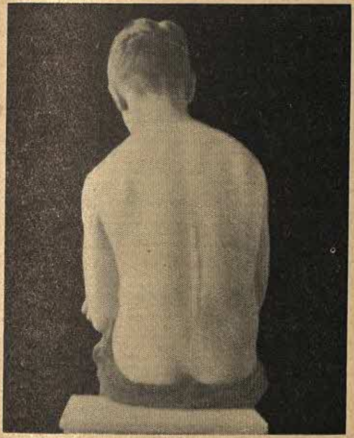


FIG. 9
Sitting with Legs Crossed

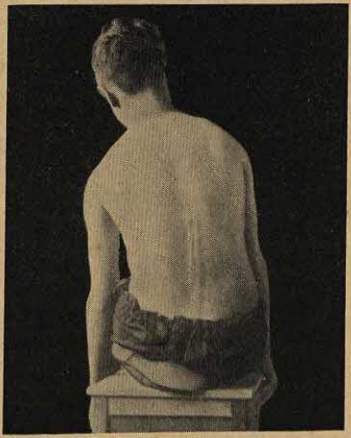


FIG. 10
Sitting on one Foot

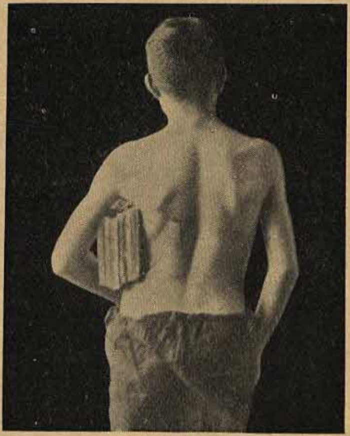


FIG. 11
Carrying books under one arm —most people habitually use one particular arm for this. Both should be used in turn

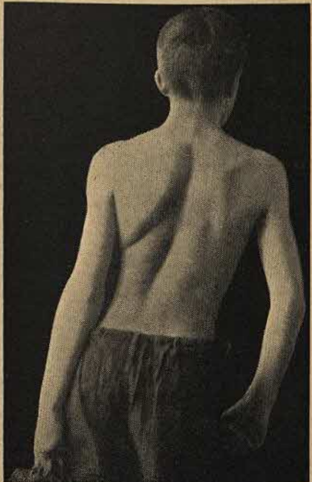
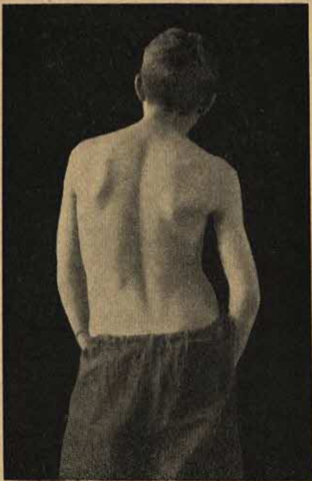


FIG. 12
Weight carrying. This deformity often becomes fixed in boys who carry milk

FIG. 13
Standing with weight on one leg—a very common fatigue posture



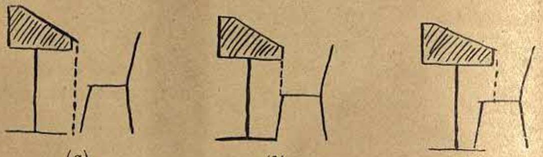
Figs. 9–13 show lateral distortions of the spine of the above boys caused momentarily by common acts or postures. Any of these tends to become a deformity if it is continued without check.

depends upon our expectation that an action oft repeated will become automatic. So our practice in establishing posture rests on a similar expectation. Why do we ask a young child to stand and walk upright? Because we hope that constant exhortation will establish an automatic habit. Possibly if some of us had a clearer understanding of the effect of posture upon function, particularly breathing, our exhortations would become more insistent and emphatic. Hence it is important not to allow a child to repeat a bad posture, for we know that such repetition must tend to establish an habitual mal-posture. The illustrations of faulty postures need no explanation. They show the fault, its cause is obvious and the correction equally so. Exaggerated curves of the spine forward or backward are alarmingly common. Lateral curvatures are also more common than is usually suspected. These latter are frequently found among girls of the Senior School age, and may disappear in a year or two. They are much more likely to, if good posture be held up as desirable, and is accordingly insisted on. Many schools have a definite posture test—more commonly for girls than boys, unfortunately. But occasional tests are not enough; it is the habitual carriage that matters. Consultation with the physical training teacher should resolve any difficulties in individual cases. During the course of the day, a teacher must often be struck by the remarkable postures assumed at times by his pupils. These are generally fatigue positions, assumed either because of fatigue or to avoid its onset. Opportunities for change of position are most valuable, and remember that a consistent fatigue position habit brings about a deformity in greater or less degree.

Fatigue and Rest

The curve of both mental and physical effort demanded of a child during school life has, during the twentieth century, progressively moved higher in that region that represents the years between eleven and fifteen. This is a matter for more serious consideration than it commonly receives, within the sphere of education proper. It must suffice here to call attention to the arrangement of the time-table of a school. Of course to interfere with a time-table usually is to bring the school world tumbling about one's ears, but, at the risk of such a catastrophe, it is suggested that many more arrangements are possible in a time-table than have usually been tried. Some weight must be given to the possibility of the onset of fatigue, if merely for the reason that the work will suffer! Certainly the children will; and they, after all, are the first consideration in education; a proposition that, to do them justice, teachers modify only by doing violence to their own convictions.

Faulty ventilation, bad arrangement of lessons, a misconception of the amount of nervous and mental effort demanded by physical training and games, pressure of exorbitant demands for homework, bad seats, improper lighting, domestic and disciplinary worries, fear of inability to do work, the over-application of competition in work and play, all tend to hurry the onset of fatigue—not to mention more fundamental states such as mal-nutrition and lack of clothing and warmth. And, in a state of fatigue, the body (including the brain) is incapable of its greatest efforts, even of its normal ones.



(*a*) PLUS (*Bad*)

(*b*) ZERO

(*c*) MINUS (*Good*)

FIG. 14

Relation of Seat to Desk

In this sphere the teacher must try to delay the approach of both mental and physical fatigue by avoiding the above conditions in practice. Fresh air, movement, and change of interest are his best weapons unless rest is indicated. He cannot supervise the hours of sleep of a child, but he can help to prevent their being needlessly curtailed; and sleep is the best of all restorers.

Again, the use of muscular effort to avert *mental* fatigue is common, and rests on a sound basis; but recreative play is the only safe form of activity for producing such an effect. A good modern physical training lesson demands as much *mental* concentration as any other lesson—in fact, the better the lesson the greater the demand—and should not, therefore, be used in a vain attempt to avert mental fatigue. The free activities of such a lesson do not turn it into a recreative period, but are included principally to counteract the rigour of the lesson itself. A purely recreative activity (two or three well-known country dances, or a simple game without coaching) for a short time is the best relief. Such an interlude does not rank as a physical training lesson.

Pressure of High Competition

Training, in its usual sense as a preparation for special effort on the games' or sports' field, is merely an attempt to accustom the body to abnormal effort in the presence of certain waste products, but as there is strong evidence to show that this lowers resistance to disease, and checks growth, it is unsuitable for the children under discussion. Competition of all kinds is a fruitful cause of fatigue, and should be strictly controlled among children. One hears much of "healthy competition" on speech days, or before the presentation of athletics prizes, but one is constrained to think that stronger efforts could be made to keep it healthy. It is an excellent incentive to effort, but loses its value when it becomes an end instead of a means.

In all instances where mental or physical fatigue is present in abnormal degree, the assistance of the S.M.O. should be sought without fuss. It is probable that a clearer understanding of a case may enable the teacher unobtrusively to make things much easier for the child.

Remember that the speed of removal of the waste products of fatigue, as well as its rate of onset, varies with individuals, and also with the sexes somewhat. In a selective school there is a possibility that the children have become accustomed to a longer concentration than the majority in a non-selective school, but one cannot avoid the reflection that the ability may have been acquired at a price. It is possible, under conditions that normally would bring on fatigue, to urge children to a further mental effort, but at what a cost! The fact, then, that a child does not come to a full stop is no criterion of the absence of pressure.

The "victor ludorum" type of championship is not one to recommend itself to a teacher whose first care is the good of the children in his charge. It sounds rather imposing, and looks well in a newspaper paragraph, but a few moments' reflection will discover the dangers inherent in such a competition. Also, excessive exertion is often undergone "for the sake of the house" or in the name of some similar loyalty—all, no doubt, excellent training, if one can be certain that it is not undertaken at the expense of normal growth, for no check in growth is ever really made up, and, after all, competition has many forms awaiting discovery by those who know nothing but the old-fashioned adult forms of it. No one is more unsparing in his efforts to promote the mental growth of a child than a teacher, but it is feared that a similar eagerness to promote normal *all-round* growth has still to make its appearance in many cases. Representative teams for inter-school and inter-town games can be fruitful of overstrain, and, in most lively schools, examples can be brought to mind of players remaining in the team for a special match, when they are really unfit, in order that the school may not be "let down." An intelligent head teacher can find a way of preserving this spirit without reaction upon the health of a child at a critical period of his life. The strain endured during preparation for examinations at an abnormally early age is already recognized by the teaching profession.

Eyes and Teeth

Detailed instruction in the structure of these is rendered almost unnecessary for health by the care taken in the school clinics, but both could well be discussed with classes of older children. Lessons on eye structure offer excellent opportunity for correlation with science lessons on light, and those on teeth with chemistry lessons on the action of acids. The teacher, however, must exercise a keen supervision on habits likely to influence either eyes or teeth. The clinic will attend to all cases of defective sight, but the teacher must see that, where glasses are prescribed, they are worn, properly and regularly.

Reading and writing postures and the system of lighting are important in their effect on sight. The textbooks used, the position of the blackboard and the handwriting thereon, and the nature of illustrations all affect the sight. Needlework periods come best during daylight, and care should be exercised in the use of cottons, silks, wools, or any other materials used for embroidery, etc., of the same colour as the material on which they are used.

The use of the toothbrush should already have been established and must be encouraged. Some schools supply brushes and paste and thus keep a check on habits as well as save money. Clean white teeth are fundamentally more important than clean collars or shining shoes.

THE TEACHING OF HYGIENIC PRINCIPLES

What the Human Body Is

We must remember that we are teaching children and set reasonable limits on this section. It is enormously wide; and it has been a common fault in the past to attempt so much that little or nothing has been achieved. The manner of presentation here has therefore been kept studiously simple, as befitting those to whom it applies. The boundaries of your topics will be governed by the interest and capacity of your scholars. Both boys and girls will enjoy the conception that the body is a super-engine. It is a faulty analogy but useful. The contrast between them leads to the mystery and poetry of life and death. The body does all an engine does, but it can choose, and does vary, its movements; repairs itself, and can function for years without supervision. Contrast the parts of an engine with our cellular specialization, but carry on the engine analogy: it will provide a convenient vocabulary. Emphasize the one-ness of our body mechanism; for that is the essential idea of health. Make the geography of the body very simple, and avoid charts filled with details and Latin names. Make your own diagrams and keep them simple—as simple as those given in these pages. Have a plan of campaign—some teachers begin with the framework and clothe it, others begin with food, as being obvious, and bring the rest in on the way. Choose your own method and follow it, linking everything up in a unified whole.

The Framework

References must have already been made to simple cellular creatures without bone. In order that all our soft parts may not just slump together, in one soft shapeless mass, we must have something to hang them on, or support them in some way: legs and arms would otherwise be like limp pieces of rope, without being as durable. Besides, we have very delicate parts that need protection. The most delicate is the central office or brain. This needs a good strong house, the *skull*: this consists of the box part, containing the brain, formed of flat bones meeting very closely at their edges; and also some rough bony parts in front, which make a framework or basis, upon which our faces are modelled. There are tunnels through into the box for communication wires (*nerves*), but especially one great hole in the base; for part of the brain is, as it were, pulled out into a long cord, and this is housed carefully, in a long bony tunnel leading downward from the base of the skull through the spinal column. In order that no hurt may come to this delicate central mechanism, it is very carefully packed in the skull, so that it will not rattle, and is practically floating in a liquid, which prevents shocks and keeps everything nicely oiled.

Situated in the front of the skull are the lookout holes, the loud-speaker, and the receiving mechanism; hence it is important that these should be well above the ground. (The upright position should receive attention during the biology course.) The skull, then, is raised, and its support is the spinal column. This column must have a motor mechanism below to move it about. It is fixed very firmly at the back of a sort of bony basin, at the sides of which are attached the locomotive mechanisms or legs. Arms to hold things are attached to another girdle a little below the head. This is not so heavy as the bony basin or girdle that supports the spine; because it has not much weight to support, and needs to be capable of a lot of free movement. Below this shoulder girdle is a flexible cage to protect and hold the ventilating and pumping stations.

This is a good working basis for the beginnings of structure. Hands and feet are self-evident, and a knowledge of their detailed bones is of doubtful value at this stage. If they must be given, leave them till much later.

The Spinal Column

(See Fig. 15.) This is very important as, with the head, it is the most important factor in carriage. It is not the main pillar of the trunk, but the only one; and is the only bony support we have between the ribs and the pelvis. Firmly fixed into the latter, so that they form a solid combination, it can thus be used as a column to which the chest may be attached. It must, however, be remembered that the spine itself is not a rigid rod, but, since it is the only pillar of the trunk, it must be made in such a way as to be flexible, allowing of body bendings and twistings. Thirty-three bones placed one on the other build this column. The lowest nine are arranged to form a strong base where it fits on to the pelvis, but the others must be able to be moved a little. They are not all of the same shape, but we can think of them as small cylinders, strong, with a hole through each and pegs sticking out of the sides and back. Piled one on the other the holes through these bones (*vertebrae*) make one long tunnel, and the pegs are used to fasten them all firmly together, so that when we bend they cannot slip off one another very easily. The cords that tie them together (*ligaments*) are not loose, but seem to grow out of the bones. These cords are strong and flexible and go along and across the bones, tying them just firmly enough to be safe but allowing the rod to bend. Between the bones are pads of cartilage, and, where bones do touch each other, there is the usual provision of smooth surfaces well "oiled." The cartilage pads have a threefold purpose: they help to keep the bones together firmly, they serve as buffers between the bones, so that the landing after a jump does not cause the bones to crash together, and they help to make the spine more flexible. The cervical, dorsal, and lumbar regions should be marked and the natural curves shown. These curves are normal, and ANY departure from them is not. Any deviation from one normal curve affects the others, since the spine is flexible and has to keep the body and head upright. We can hold it in a sloping position, but not for long, as this is very fatiguing. This forms the basis of all talks on posture, and, as every important organ is carried near the spine, when these are discussed later it can easily be shown that a deflection of the spine from its normal curves is bound to affect the organs carried and partially supported by it. So that good carriage is not good only because it looks well, but because it enables all the things inside the body to work properly, and to have enough room. The commonest departure from a normal curve is an exaggerated lumbar curve (*hollow back*), Fig. 7. Round shoulders often mean that the dorsal part is curved too much (Fig. 6).

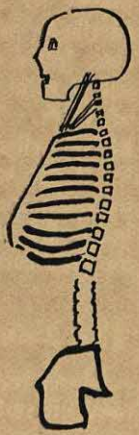


FIG. 15
Spinal Column and Chest
The thin lines from the top of the breastbone to the skull and the neck represent muscles

The working of the *axis* and *atlas* may occupy an interesting few minutes. Children know the words, and the story of the origin of the word "atlas" will help to fix the explanation of the mechanism, which, from a health point of view, by the way, is not of great importance, but is nevertheless interesting, and illustrative of the economical structure of the body.

The Ribs and Chest

A glance at a diagram such as Fig. 15 will help to impress on children the necessity for a strong spinal pillar, since the rib-cage is fastened to it like a box to a pole. Inside this box, or cage, are two most important parts of the internal works. It could not have been a solid box like the skull, because of what it has to do. The bony hoops that go nearly round to form the chest are each in two parts that meet at the breast-bone in front (all but two pairs), and at the vertebrae at the back; so that really the spine is part of the rear wall of the chest. The ribs have to swing up and down when we use the chest in breathing, and they pivot where they touch the vertebrae (*joints*); and here again the junctions or joints are well oiled, just as they have to be in an engine. In front, all but two pairs at the bottom are joined to the breastbone by tough flexible cartilage, which makes it a safe kind of box that gives a little when it receives blows or squeezes in games, and fights, and some kinds of work. The bottom two pairs are called floating ribs, and are obviously easily squeezed in, if one wears tight clothes round that part of the body. The weight of the chest is partly borne by the muscles shown between its top and the cervical spine and head.

The Two Girdles

These are the pelvic and shoulder girdles, and may with advantage be compared and contrasted with regard to their structures: these reflect their functions.

The pelvis (Fig. 16) is like a wide basin—it is particularly wide in humans—slightly tipped up at the back. It has to help to support a mass of long soft tubes that could not be conveniently supported on anything flat. Its strong key position has already been noted, and it should be shown how any tilt forward or backward will make it a less firm support for the pillar, which is "spliced" into the back of the saucer-shaped pelvis like the handle of a bat into the blade, to make a good firm joint. Notice how everything makes for strength in this region. It must be strong; for this pelvis comes between the spine and the lower limbs, and must bear the stress between them. Two sockets slightly forward at the lower sides take the ends of the thigh bones—smooth, well-oiled sockets, so that there is easy movement. The girdle is a complete and rigid one. The upper side edges are the hip bones, which can easily be felt. The topography of this structure is difficult and seldom understood by children. The simplest explanation is best at first.

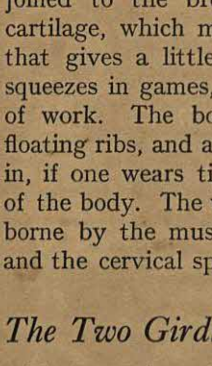


FIG. 16

Rough diagram of Pelvic Girdle

The other girdle is not really a bony girdle at all, as the bone does not go all round. The front part (*collar bones*) rests on each side of the breast bone, and the rest is just the *shoulder blades*, which are jointed to the collar bones. The shoulder blades, which can easily be felt with the fingers, do not touch each other—in fact in many children they are far enough apart to produce a deformity—but the belt or girdle is completed by means of muscles. It must be remembered that the arms are attached to the shoulder blades. All this should be developed to show how loose the shoulder girdle is, its main attachments to the trunk being muscular; and that therefore the carriage of the shoulders, and hence the position of the chest (the collar bones rest on the front upper border of the chest—the *breast bone*), are dependent on the vigour and usefulness of the muscle groups in this locality.

The Limbs

The legs form two pillars that support the pelvis and everything else. The thigh bone (*femur*) is a long strong bone, with the top part turned about half-way at right angles, so that it can be fitted into the sockets made for it in the pelvis (see Fig. 16). Below the knee we have the leg: two bones firmly knitted together, the shin bone and a much thinner one.

Compare and contrast the bones of the lower limb with those of the upper, noting the difference in weight, and the fact that the two bones forming the forearms are allowed to slide round each other, in order that we may make more complicated movements with our hands, not needed in the case of our feet. If we stand on our hands we find the two pairs of limbs rather similar. The bones of fingers and toes, wrist and ankle, should not be treated in great detail. Note that in wrist and ankle the bones of the joint are small, slide against one another, and are intended for much free movement. This free movement has an attendant drawback, in that these joints cannot therefore be as secure as others, and are often injured.

Summary

This is a mere outline of the framework. Details may be added only as they can be assimilated. It certainly represents a more intelligent survey of the skeleton than the great majority of children possess, and contains the essentials. A knowledge of it enables the topography of the body to be easily grasped; and is a good basis for posture teaching. The integration of the body framework with the rest of the body must be insisted on, e.g. growth of bone and the effect on it of unsuitable food; the function of the marrow and the presence of blood vessels all help in this. The use of bones as levers should be referred to the Physical Science lesson.

A Living Child

For simplicity and clearness we must now treat each system or organ alone; but it is first necessary to present the whole in a very simple manner in order to emphasize its unification. It would be good to refer here to the Super Engine idea, showing the tremendous superiority of the body over an engine. Wires of communication (nerves), the motors (muscles), digestion juices and secretions, lungs, blood, and waste, should be mentioned, and their processes very roughly described in order to show their intimate connection. Picture the whole, also, as a well arranged state, with citizen groups working together in a team, each having its special duty and usurping that of no other group.

This general survey is often omitted. It can come easily after the framework, and helps to knit closely together the different sections that follow and that must be treated separately. Again, let it be emphasized that the wholeness is the essential idea that must be thoroughly grasped before details are examined.

The Great Tube

(See Fig. 17.) Some of the ills that flesh is not "heir to" come to the great digestive tube. These are mostly "earned increment," the earnings of ignorance, which the teacher must attempt to replace by simple but sure principles. Try to treat structure and function together as much as possible, with emphasis on the latter. The past error has been to put it on the former, and, if we are honest, we must acknowledge the fruitless result of that error. The simple treatment of the framework enables us to give, graphically and very rapidly, a fairly adequate idea of the topography of the body. Detailed lists of names of bones, organs, blood vessels, nerves, muscles, etc., apart from their specific functions, are valueless at this stage (and at any other). Very simple diagrams are now absolutely essential.

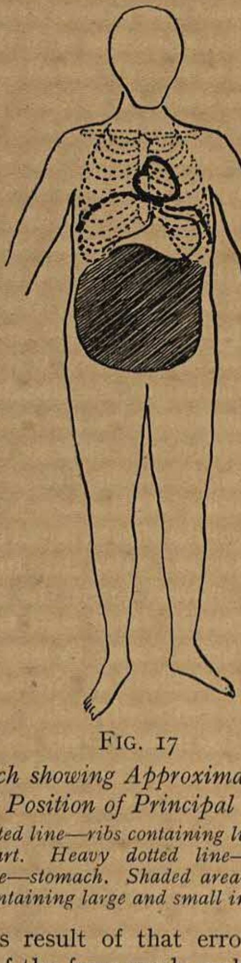


FIG. 17

Rough Sketch showing Approximate Size, Shape, and Position of Principal Organs

Thin dotted line—ribs containing lungs. Heavy line—heart. Heavy dotted line—diaphragm. Thin line—stomach. Shaded area—abdominal cavity containing large and small intestines, etc.

Food is so evident a phenomenon of life that it makes a good starting point. Lively questions will obtain a child's idea of what happens to food during its entry into the body, and enable a teacher to choose intelligently the points of emphasis. From this stage the children should become accustomed to references to parts of the body not usually referred to except during disease. The teacher must help the children over this awkward stile as soon as possible, and the more familiar all become with the functions of the body the more easily are all parts referred to without comment or giggles. Before food enters the white gates (teeth) it is always well examined by vigilant guards: the eyes and the nose. They oppose admission to any enemies, and it is astonishing how man and the animals thus are able to avoid most harmful foods. Having entered the upper end of this Great Tube, the food is immediately dealt with very drastically. The teeth cut, tear, and grind it—thoroughly, if we chew wisely. It is rolled round and round by the tongue, and already the central office of communication has got into touch with things, has dispatched a message to small factories called glands, of which there are six with little tubes leading into the mouth. Their work is to collect from the blood a liquid called saliva, and to release it along the little tubes into the mouth, when ordered to by the nerve centre whose work this is. Good staff work is done here, for the saliva comes in larger quantities just when it is needed: on the entry of food. Of course it is constantly being collected and released into the mouth. This liquid moistens the food and changes a part of it—some of the starch—into sugar; because this makes more useful fuel later. It also makes the food easier to taste and, as it has to pass the taste buds at the back of the tongue, this is useful. These taste buds are the last guards. We all know what happens if they discover an enemy.

The food having been dealt with thus, the tongue rolls it into small lumps, and sends them to the back of the mouth. It now has to pass into the first closed part of the tube (*gullet*); but as there is another important tube just in front of it (*windpipe*), which has nothing to do with the disposal of food, the nerve centre communicates with muscles that neatly clap a lid over it, and the food passes safely to the tube at the back. If, by accident, the lid is a little late, and the tiniest bit goes "down the wrong throat," we cough and cough to get rid of it —nothing must go into the wrong place. The action of the gullet is well demonstrated by a piece of india-rubber tubing and a pea, and illustrated by telling how a man hanging upside down can still swallow food. Having been worked down to the bottom of the gullet, each lump of food is passed through the gate to the *stomach* by means of a circular shaped muscle, which opens, after a nerve warning. The position of the stomach should be clearly shown, with its comparatively small share of abdominal space. Picture this organ as a large factory surrounded by thousands of smaller ones making acids and ferments. Muscles arranged longways and across enable this bag to become a kind of churning mill. Describe how the food is here chemically changed into products that are easily passed into the blood. Small amounts only are allowed to pass out of the other gate of the stomach, and these only when ready—no large pieces can go. Thus, a good meal takes some time (even hours) to go through the whole stomach process. The stomach machinery works hard, needs rest to get ready for its next work, and therefore must not be asked to work on more food between meals. When everything is all ready again to start work, the nerves let us know, and we feel hungry once more.

Having left the exit of the stomach, which has closed behind it, each bit of changed food now enters a twenty-foot tube, which has to be coiled round in waves and curves to be packed into the space. This is the *small bowel*, or *intestine*, which also depends on the spine for support. Digestion is not completed in the stomach, but continues here. Starchy digestion in the mouth, protein in the stomach—explain what each supplies to the blood, which it reaches through the tiny microscopic blood-vessels that are arranged all along this food tube. Keep the explanation simple and interesting of how the *liver* and the *pancreas* pour juices into this tube, and, by changing the fats into soap, enable them to get through to the blood, where they miraculously become fats again—but human at now. The large surface area of the small intestine also has a purpose, and by the time what we have eaten has got to the end of the Great Tube nothing but rubbish is left, all the valuable parts having come into contact with some part of this large surface, been carried away, and passed into the blood. The action of the pancreatic juice on starchy and sugary foods, well explained, gives the children an intelligent idea of why honey is good for swimmers, why hikers carry chocolate, and also why we must have a storehouse like the liver to keep some sugar in stock, ready to be issued to the blood immediately a message is received that it is running short or needs an increased supply. The duty of the liver as a storehouse and great factory, the result of the entry of more fat than can be used properly, and the evil results of too much protein (the repairer) should all come at later stages. One of the puzzles to children is why all the liquids in the body do not start flowing all over it—the Science lessons can help here by experiments showing the action of membranes placed between two liquids, as well as the action of ordinary valves.

At the end of the small intestine is a valve, which allows things to go through but not back again. Here what is left of the food—very little useful stuff—is passed through the valve, and is rolled about in a much wider tube, until everything of any value to the body is extracted and absorbed into the food transport system. What is left is ejected from the lower end of this *large intestine*. It is ejected by muscles, which act as most of our familiar muscles act: only when a message is received from headquarters. In the case of liquid waste, there is no need for a similar headquarters message. If too much is collected we feel pain or immediate discomfort, and hence do not neglect this. But, in the case of the waste from the *bowel*, we can neglect to use the ejecting muscles, and leave the waste in the bowel. Now, we all know that waste, left in pipes, clogs them; and the same thing happens here, only more so. Any forgetfulness about this matter sets up all sorts of trouble inside the machinery; for the body cannot use this waste, and it is harmful to it, so out it must go regularly.

The Blood

Enough has been said in the last section to show that the blood is the food transport system of the body. Give a brief explanation of how large numbers of the tiny capillaries lie close round the food tube, receiving the food. This is a good opportunity for explaining why the food must go through its different physical and chemical processes, in order that it may be reduced to such a condition that it can be enabled to pass through the thin walls of the vessels. The manner of presentation should be on similar lines to that given for the digestive tube, and should bring out the following facts.

Besides gathering useful food from the food tube by means of the lymph, the blood also has another "round" through the lungs, where it picks up oxygen and deposits waste (CO_2 and H_2O). It has a kind of brother in the lymph, which also circulates. How does blood go up and also down? It has a pump. Illustrate the strokes of the upper and lower hearts with a rubber ball on a tube, or two fists one on the other, opening and closing in rapid succession. Arteries, which carry the blood AWAY from the heart, are elastic and have no valves, but elastic walls, which squeeze the blood along. Let it be felt, and count the beats resting, and after a few jumps. Get an average for the resting readings. Tell the story of the meaning of the word "artery," and how it arose, when the circulation of the blood was unknown. This is a good opportunity for a short history of Harvey's discovery. The successive branching to the tiny capillaries must be carefully taught, and the bathing of the tissue cells with liquid, which can just squeeze through the capillary walls—lymph. This continual bath in warm liquid food is like the A.S.C. in the Army, except that in the Army the supply officer distributes all the different kinds of supplies each to the proper unit; whereas in the body the whole collection of foods is carried round, and each marvellous cell chooses just what it needs; and we have seen that there are many different kinds each with a special job, and needing special material to do it. In a healthy body they never make mistakes by choosing the wrong stuff. The return to the heart is difficult and seldom understood; for not only must the blood with its red blood cells, which have never left the vessels or tubes, be brought back, but also the liquid which oozed out carrying food has also to be returned. This gives two return systems: the veins and the lymph vessels. Once this is grasped the rest is patient explanation with copious analogies.

The force, which pumps the blood from the heart, is dissipated in the capillaries, and so elastic veins, to carry it back, would hardly do; hence the valves, which are like swing doors that say "Push" on one side, but have nothing on the other side, and so open only one way. Experiment with the superficial veins to show the valve action. The lymph is also returned, but it does not get much help from the heart beats. Every movement we make—and parts of us are never still—helps to move the lymph on in tubes also fitted with valves.

Blood and lymph carry back food to the heart but they are also carrying waste, the result of the burning or combustion going on in the tissue cells. It goes on in all live things. The veinous blood is cleansed in the lungs, and the lymph in the lymph glands; and both join up just below the neck. Children will be interested to know that blood circulates about every 1½ or 2 minutes, and that a man has about 14 or 15 lb. or pints in his body. The formation of a clot outside a wound to stop a leakage of valuable blood may also be mentioned. The duties of the red and white cells of the blood are for later lessons, and help revision, references being made to bruise swellings and their cause; and the renewal of fibres, which later become hollow and make new small blood tubes (also cf. white scars). The white blood cells can be most graphically discussed—their scavenging, defence, and their attack on intruders.

Geography of the Circulation

This must be simple at first, and in diagram form. A few names, positions, and functions of veins and arteries may be given, but only the important ones, e.g. portal vein; the superficial veins are most interesting to children. The structure of the heart, with its strong valves, may be shown by a simple model, made roughly with flaps for valves, but its value is doubtful. A sketchy outline of this system should already be known to the children of the Junior School, and therefore details are not given. The extension of the blood system to every part of the living body must be insisted on—even to the bones, in whose marrow are busy factories making blood cells to be sent out through tiny tubes into the blood stream. The size and position of the heart, and the effect of a concentration of the blood supply in one locality while another is really needing it, blushing, pallor when cold, colour of arterial and veinous blood, effects of cold and hot baths on the superficial and other blood vessels, are all matters which teachers will surely discuss.

Breathing

The connection between ventilation and breathing is obvious, and becomes of greater moment to children after they understand the mechanism of breathing, and the change in air before and after it has been expelled from the lungs (see Fig. 18.)

The mechanism has been very briefly described and may now be developed by reference to science lessons in Physics (vacuum, etc.). The swinging of the ribs may be shown by a small model, or by reference to the handle of a coal-scuttle, in order to illustrate that their raising increases the cavity of the chest. Measure some chests to show that this is so. Get rid of the idea that we suck in air in order to inflate and swell our chests, and refer often to the necessity for keeping in good condition the motors that raise the walls. In fact, if a teacher wishes to work out for his class the logical reasons for insistence on good posture, here is an excellent opportunity for showing the importance of an erect spine, and a good strong apparatus for breathing. Reference to singers and elocutionists will give point to the argument.

Simple experiments with lime water will have been done to show the presence of CO_2. Apply them; if necessary do them. Show on the main diagram (Fig. 17) the position and size of the lungs, which represent the laboratory where the exchange is made of passing out from the blood waste products in the form of CO_2 and water, and receiving, in exchange, oxygen from the air that rushes in to fill the swelled chest.

Refer to the lid on the windpipe (already mentioned)—how it is open for the air that we ought to receive through the nose; so that the warm moist passages there warm and moisten the air before it enters the main apparatus, which should not receive the shock of dry cold air. There are small hairs also in the nose passages that catch most of the dirt, which is practically invisible, so that it does not get into the lungs and clog the machinery there. If we want any proof of this, our handkerchiefs will show it, after we have been out in a mist or fog; for a fog is only particles of dust surrounded by moisture, and your handkerchief shows how much has been prevented from entering your lungs by breathing through the nose. Nose breathing is worth spending some time on. Any bad mouth breather may be forced to breathe through the nose, by his taking a pen holder by the end between his *lips* and holding it there. The effort will effectively close the lips and he must breathe through the nose. Explain why we breathe through wide-open mouth in swimming, and often in singing (in both cases a large quantity of air must be inhaled in the shortest possible interval, and this can be done only through the wide-open mouth; of course this is only occasional in singing, but it is invariable in vigorous swimming).

Equally important with nose breathing is the voluntary use of the diaphragm. Its position, how it forms the floor of the thorax, and its peculiar action of contracting to increase the lower chest capacity are all worth spending time on. Let a child (preferably in a swimming costume) lie supine, and show the action of the diaphragm and chest in breathing (see Fig. 18). The diaphragm is one of those marvellous muscles that go on working, contracting and letting go, regularly all our lives without any interference by our wish. Try stopping your breath. There is a kind of automatic telephone at work, more wonderful than any we find in the post office, for it does the sending and the answering itself. If we stop breathing the blood is being starved of oxygen, and the little red cells begin to complain as they are sent along to the part of the central office that controls breathing, and immediately a message is sent to continue breathing—a message so peremptory that we never can refuse to obey. This part of the brain, the lower part, looks after quite a number of "machines" that have to go on without our knowing, even when we are asleep, such as the blood pump, the breathing apparatus, and even the movements in the Great Tube, of which we know nothing unless they go wrong.

Calm breathing goes on automatically, and so does quick, and even deep breathing, when we work very hard and vigorously in a netball or football game, but we can also take deep breaths if we wish, taking in about four times as much air as usual—this is a useful practice to keep the air in the lungs fresh.

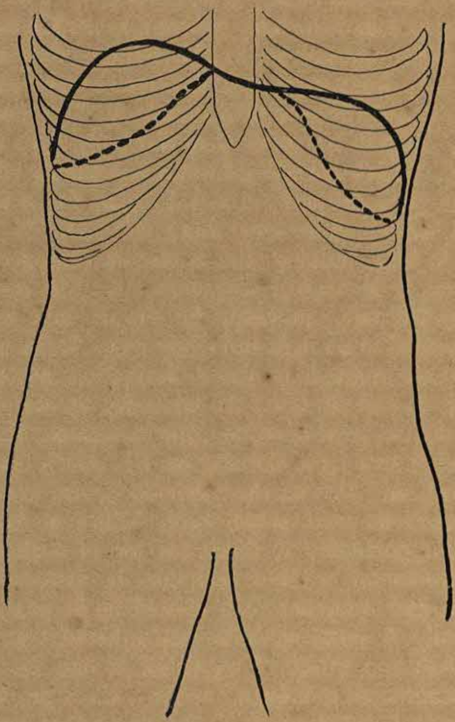


FIG. 18

Rough sketch showing Diaphragm During Breathing

Heavy line—relaxed diaphragm after breathing out.
Dotted line—contracted diaphragm after breathing in, giving greater lung capacity.

The place of oxygen in all combustion is learned in the chemistry course. Make the necessary analogy with the lung process. Describe briefly the structure of the lung with its air sacs, whose very thin walls are surrounded by tiny blood vessels. Here is one of the busiest factories of the body. The waste stuff in the blood has to be burned up to get rid of it. This uses up part of the oxygen, and, like all burning up, gives heat to keep us warm, and CO_2, which we all know about. Some of the oxygen is taken into the blood, to be carried by it on its journey round the body, where it is used to burn up other substances in the tissues—this also helps to keep us warm. We breathe out what is left, and the new things made by the "burning," as well as water that the body does not need. This breathed-out water is probably what helps most to make crowded rooms feel stuffy and nasty—more even than the CO_2. If the air is kept moving, the stuffiness disappears; unless it is beyond improvement. The water breathed out can easily be shown, and even measured in a rough and ready way. Refer here to other methods of water elimination, particularly to perspiration; the necessity for keeping the skin in good condition, the bad effects of too much warm tight clothing on the skin's mechanism, and also on the methods nature uses to preserve an even temperature. This is an excellent opportunity to teach the use of a clinical thermometer without reference to disease—at least any reference to it should be in passing. Finally, it must again be remembered that although too much of anything is bad for us, draughts and moving air are two of our greatest friends, for they carry off the waste that comes from other people. We have no use for it, and to be forced to use it, instead of fresh air, is merely to invite enemies to our most important workshops, where they may do incredible damage. One especially is a particular enemy of ours, and he sets up consumption, when many of us could have kept him out.

The Motors

All movement is performed by the muscles. Each of these is a complete little motor in itself—and more, since it is self-repairing. There are two kinds of muscles: one pale coloured and the other the red meat of the body. Some of the former never stop, even when we sleep, e.g. the heart and breathing muscles, hence they must rest as they work; others of this kind are the stomach muscles, those round the Great Tube, etc. The red meat muscles are those we can feel on our arms, and legs, and body. These are the quick-moving ones. They are shaped rather like air ships, but thinner at the ends; you can see this when you eat a rabbit. Each red muscle is made up of bundles of long fibres, each in its own sheath. The bundle also has a sheath. There are wires of communication to every fibre, and blood bathes them, bringing food and removing waste. If so much waste is made during hard work that it cannot be carried away quickly enough, then we feel stiff until it has been removed. In a muscle there is more burning up, which gives more heat, and for this reason we perspire to keep the heat down. Here, reference can be made to science lessons and the behaviour of water in porous pots. The arrangement to keep us warm, and just warm enough, is well worth a lengthy explanation.

How the Motors Work

The bones by themselves cannot move, and the muscles by themselves would not be much good, but the two together make big wide movements as well as tiny exact ones, such as a watchmaker must use. Joint structure is better illustrated than described, and the best illustration is a real joint: articular cartilages, sinovial fluid and membranes, capsule, and ligaments are thus shown easily and definitely. Very rough dissection is all that is needed.

The muscles taper and are joined to tendons that are in their turn joined to the bones. The tendons can be felt at the *Achilles* and the wrist. Refer to mechanics lessons for levers, and discover the different orders in the body. The muscle fibres can do only one thing: contract. Then they let go again. Show how all muscles are arranged in pairs, and each is controlled by its antagonist. Children are much interested in movement, and this section must be extended when talking of the nervous system. There are an enormous number of muscles—about 300 are brought into play to walk a step, each beginning and stopping contraction at its proper time. The central office does this controlling, and all muscles are in close touch with it. From babyhood, everyone's central office is learning how to exercise the necessary supervision to work large numbers of muscles in a smooth and controlled manner. Some do it better than others. At the beginning everything is difficult. Watch a baby trying to put one of his toys into his mouth. He keeps missing at first; then he learns, and everything goes there as he practises his new accomplishnemt. He has to learn to make sounds we can recognize (babies in Africa and Asia learn to make quite different sounds from ours). Then he has also to learn to use his legs and arms; and that is why it is a good thing to let him lie on his back, and kick his legs, and wave his arms freely.

Then we must keep on using our muscles. Exercise for all of them is imperative. A muscle unused gets smaller and weaker, and finally is quite useless, and our red muscles help our inside works quite a lot, especially those muscles that are around our trunks. If they go slack, then our bodies assume very comic shapes. Exercise, cold water, and rubbing to keep our skins clean to do their work, all help to keep our muscles healthy, i.e. of a good "tone."

Communications

All the different engines and factories, pumps and levers, motors and waste ejectors must have a master. This master is situated in the brain and spinal cord, and he has fine white "wires" connected with everything that grows and works. This master has a principal centre and sub-centres. This whole system is much more wonderful than, although not so quick as, the wireless broadcasts; because with the latter we cannot answer back with the same mechanism however much we wish to, while in our system provision is made for every possible contingency (almost), even for some kinds of breakdowns, which mend themselves. The principal centre is the Big Brain, and the subcentres are in the Little Brain and the Spinal Cord.

The Big Brain

This can best be described to children using the above kind of language, bringing out the following. It is encased in three skins for protection and food. The outside of it is grey, made of highly developed nerve cells with tiny branches intermingling with others so that communication can jump across to keep everything in touch. One branch is a white one and many join to form a nerve fibre. Some are long and some short; some go to special organs (sight, hearing, smelling, etc.), some to muscles as far away as toes and fingers, calling on the way on the Spinal Cord, which does some of the work. Enlarge on the higher duties of this part of the brain, and the crossing of the fibres to the opposite side of the body through the *Pons*.

The Little Brain

This is underneath the Big Brain. Its function is not well known, but here the work of balancing, respiration, and circulation is done, as the Big Brain, which has to do the memory work and thinking, as well as all the overseeing, cannot be bothered with them, since they go on almost all the time.

The Spinal Cord

(The position is already known.) It is a continuation of the brain, only the wires were crossed as it left the skull, and, also, now the grey matter is inside. It comes through the large hole at the base of the skull. The white nerves join in pairs, and mostly, those at the back bring messages in from the skin, etc.; and those at the front take messages out to the muscles, and are called motor fibres. Some nerves have both sets—both "in" and "out" fibres.

In and Out Fibres

These must be explained. The work of the higher centres, and that of the lower, is interesting to children and important in education. Reflex action should be traced through its course, and different "reaction times" found in different children. Memory and thought, reasoning and contemplation, must be referred to but not at length. The wonder of this higher brain action is enough for a child—and for most of us. Remember the number of nerve cells is fixed. We cannot increase or renew them after birth, and must make the most of what we have, without omitting any chances of bringing shy ones to the front. This is the real reason for the so-called "crowded time-table." Education is largely an opportunity for developing the nervous and muscular systems.

Conclusion

Modern biological tendencies may impel a thoughtful teacher to feel that any education he may give will not improve the future race. This is the case only where there is that dangerous "little knowledge." NATURE and NURTURE are both necessary. It is the teacher's job to look after a large part of the nurture of the present generation—that which establishes *acquired characters*. The academic side of one's work is purposely made wide and varied, in order that numerous occasions may arise, on some of which dormant impulses may be quickened. There have indeed been cases when great intellects have been housed in weak and ailing bodies, but there is little doubt that something was thus lost to the world. The teacher must therefore look upon the establishing of healthy habits as a major part of his work. Acquired characters are physical as well as mental and moral, and the most important physical possession is positive health.

DOMESTIC SCIENCE OR HOUSECRAFT

THIS important part of education has a firm place in the modern curriculum, and, because of its wide range, affords to every practical teacher opportunities for using her own personal gifts and interests in the service of her pupils.

In the changing conditions in which education finds itself to-day, domestic science teaching is in a happier position than ever since it first became a school subject. Education is not now regarded solely as a matter of the intellect or of learning, but as affecting the whole person in all relations of life. Consequently housecraft teaching is achieving to a new significance. It is recognized as affording sound opportunities for the objective expression of personality as it develops, and therefore as an excellent means of training and disciplining adolescent emotions away from the personal, and towards the needs of others, in the home and the community.

I. *Some General Considerations*

It is usual (though not universally the case) for the housecraft mistress to be on the staff of the school.

She will therefore need to give earnest consideration to the general organization of the school as arranged by the head teacher before drawing up her syllabus.

She should have information on many of the matters enumerated below—

1. The age at which instruction is to begin if housecraft is not taken throughout the entire Senior School period.

2. The time that is to be given to the subject in each school year.

3. The method on which girls are grouped or graded, and the need for varying treatment of subject-matter with quick and slow stream pupils.

4. Local arrangements governing admission from Junior Schools. Practice varies and in some districts promotions are annual while in others they take place twice a year.

5. The arrangements for science teaching. In some cases it is possible for the housecraft mistress to undertake certain parts of a general course in science.

6. The housecraft room (or rooms) and its equipment.

7. Local conditions of work and of women's employment. The economic conditions under which the pupils live.

It is desirable to consider these points rather more closely, because cases will no doubt arise in which the head teacher may wish for the specialist's point of view.

The Age at which Instruction should Begin

It is often said that instruction should be given throughout the last two years of school life, i.e. from about 12 years old. Another opinion is that a younger girl starting at about 11 years brings to the work a greater zest because of certain psychological factors which are then becoming more active. A third body of opinion expresses the view that such essentially practical work gains by intensive treatment, and would leave instruction in housecraft to the end of a girl's school life, giving it then in one continuous period.

There is no final opinion on the matter, and under each arrangement girls have done well, though there are certain considerations which it might be well to keep in mind. If instruction begins during the first year of Senior School life, having regard to the physical strain of long periods of practical work for young girls, shorter lessons might be arranged.

The physical aspect arises also if housecraft is taken in a continuous period. It is doubtful whether adolescent girls can profit by intensive teaching if it involves unaccustomed physical activity over long periods. It should not be forgotten that good posture is important, whether the occupation be active or passive.

The fact that informal teaching in domestic work goes on throughout school life, from the nursery upward, should be remembered by the teacher. So too should the probability of good home training in many cases.

Time to be Allotted to the Subject

On the assumption that housecraft is taught throughout the Senior School life this plan will be found to work well—

	Term 1	Term 2	Term 3
Year I .	0 or 1 hr	1 hr.	1 hr.
Year II .	2½ hr. to 3 hr.	2½ hr to 3 hr.	2½ hr. to 3 hr.
Year III .	2½ hr. to 3½ hr	2½ hr. to 3½ hr.	2½ hr. to 5 hr.

In large Senior Schools it is often found useful to have as few interruptions as possible during the first term, to enable head teachers to assess the work of new pupils in the three R's. Therefore housecraft lessons may be postponed until the second term and a further advantage may accrue, in that third-year girls may be given the opportunity of extra time in their last term. Alternatively, if there should be a difficult slow stream in the school, the extra time might be used with profit. It may sometimes be advisable also to let a quick stream in Year I wait for housecraft lessons until reaching the second year, in order to provide the longer period for girls in the leaving term, or for the slow stream pupils. This would certainly be advisable in schools where a fourth year is included.

It is essential that at some stage the girls should have at least 3½ hours per week either on one day or on two consecutive days, so that long processes such as washing and finishing woollens, jam-making, and papering of rooms may be carried out. The last term is probably the most suitable period if it can be arranged, as the girls should then be physically capable of the work, and have a sufficiently sound background of knowledge upon which to draw for some of the more difficult phases of the work.

School Organization

QUICK AND SLOW STREAMS

The housecraft mistress will need to keep herself fully informed as to the mental ability of her pupils. Many head teachers are using intelligence tests on the results of which the classes are arranged into quick and slow streams. It is probable that the head teacher will wish to make suggestions as to the best methods of teaching the various grades. Speaking quite broadly, the slow stream pupils will, in all probability, obtain the greatest good by being thoroughly taught mechanical, repetitive processes in which they can reach a standard worthy of praise: thus gaining status in the eyes of their fellow pupils and increasing their own self-respect.

Admission to Senior from Junior School

The housecraft teacher will be influenced in her manner of arranging a scheme of work by the local rules governing admission, as well as by general arrangements for promotion inside the school. It is necessary for her to make every effort to formulate a workable scheme which shall ensure for each pupil a well-graded course of work.

Science and Housecraft

The relationship between the teaching of science and housecraft will probably be close. In many schools a general science course is given which deals with air, water, electricity, light, etc., all of which have their practical applications in the housecraft room. Provided school organization allows of it and the housecraft mistress has good science qualifications, she can undertake some simple teaching of physiological processes relating to digestion, metabolism, etc. She will without doubt deal with many of the aspects of hygiene, of the person, of the home, of the school and playground, and of the town, city or village in which her school happens to be.

Food and its properties will be discussed in many lessons, broadly with all grades but more fully and specifically with the quick streams.

Housecraft Rooms and Their Equipment

If the teacher is fortunate she may be asked to express her views on the fitting and equipping of the housecraft room; more usually she must adapt her teaching to existing conditions. Her scheme of work will be planned in the light of these conditions, but she should remember that they are not all necessarily permanent. It is sometimes useful to try fresh positions for cupboards, etc., whereby space or convenience may be improved. A coat of colour wash may transform a dismal cloakroom or staffroom into a cheerful place and provide valuable practical work, as well as a valuable object lesson for senior pupils.

It is frequently found to-day that girls work as individuals and not in pairs, and every care should be taken that the lessons are planned to ensure the use of all available cooking stoves, sinks, tables, etc.

The coal range will often be of the type provided on modern housing estates and at any rate a minimum of electric cooking and other household appliances will be installed wherever current is available at a reasonable cost.

Local Conditions

Local conditions of work and wages, especially as they relate to married women and girls, should be considered in drawing up a scheme of work. It is important that the housecraft mistress shall possess the confidence of the pupils if the teaching she gives is to be carried into their homes.

II. Aims and Scope of Housecraft Teaching

At the present time, when practical rooms are an integral part of all new schools and of many older schools which are being remodelled and undergoing structural repair and alteration, there is a need for considering what should be the position of housecraft in the curriculum.

The opportunity comes to many head teachers, probably for the first time, to make full use of the educational possibilities of this work. There is perhaps a danger that its self-evident practical or even utilitarian value may tend to obscure its educational value, and every responsible teacher of housecraft will need to bring her best judgment to bear on the problem of the true aim and scope of her teaching and practical work. Speaking in the broadest terms, the housecraft specialist might with truth state her aims as being the maintenance of the good health, well-being, and the happiness of the community. It will be generally agreed that the daily life of the school should profit by the fact that housecraft is taught, and this agreement would appear to indicate that the methods of work learnt in the housecraft room are put into practice throughout the school. When work carried on outside the housecraft rooms proper is wisely planned and adequately supervised, it affords a valuable extension of responsibility and experience, especially where there is only one main housecraft room on the building, and it affords a means of living up to the true aim of the teaching by contributing to the well-being of the school community.

Traditional methods of teaching cleanliness and nutrition will be subjected to a scrutiny of increasing intensity by head teachers and housecraft mistresses who devote thought to the matters set out in the revised edition of *Suggestions on Health Education* recently published by the Board of Education. There can be little doubt that in many schools this book will afford a new point of departure for practical work.

Schemes of Work

Where the centre system is in force, the housecraft teacher should submit her scheme of work to the head teachers from whose schools she receives scholars. This should be done in order to avoid overlapping and to give an opportunity for the closest co-operation between school and centre. It may prove necessary to discriminate widely between school and school if it is found that the scheme needs modification, in order that the greatest benefit may acrue to the general bias of each school. It is much more difficult to attain the true aim of housecraft teaching when the work is not carried out on the school block, and heavy demands may be made on the goodwill of the teachers in arranging mutually suitable schemes if due regard is to be paid to limiting circumstances which are not capable of alteration. Many of these limiting circumstances will, no doubt, be resolved in course of time, but some are likely to be permanent. One such circumstance is the joint use of a room for housecraft and manual work, but the existence of a difficult situation affords further opportunity for living up to the aim of the work, the preservation and extension of happiness.

Suggestions on Planning a Scheme of Work

It is advisable to plan the scheme on the basis of a term's work, for school organization will almost certainly make it necessary to re-group classes from time to time at shorter intervals than one year, as scholars attain the maximum school age and leave. This will render it necessary for the teacher to prepare schemes for three terms, or two if that is the local custom, in each year of senior school life. Teachers at the beginning of their career have found some such plan as the following a great help to clarity of thought.

Spring Term, 1936
Date of Commencement, April 10th, 1936.
Date of Closure, July 26th, 1936.
Total Number of Weeks, 14.

	Total Hours	Cleaning Processes, Etc.	Laundry Work	Cookery
Year I 1 hr. per week .	12	6 hr.	3 hr.	3 hr.
Year II 2½ hr. per week .	30	4 hr.	6 hr.	20 hr.
Year III 3¾ hr. per week .	45	10 hr.	10 hr.	25 hr.

Into a framework of this nature which shows clearly the total number of hours available and suggests an allocation of time for each section, it is not too difficult to build notes on the ground which may be covered. A young teacher will be well advised to make a full scheme of work. She need not be disappointed if she cannot complete it in every particular. With experience a more fluid scheme is often beneficial to the work.

Unless there are any unsurmountable objections, it is advantageous to keep the three main subjects into which domestic science tends to fall working as a whole. E.g. if cooking forms the main lesson on one day it might with profit have been preceded by a lesson on washing tea towels and followed by a lesson on washing up. This is particularly the case in the earliest and latest stages of the teaching, because it is highly desirable to relate the work as closely as possible to home-life and conditions. There is undoubtedly a stage during which a preponderance of time should be given to cookery, which is the section making the heaviest demands on intelligence as well as on manual dexterity. It would probably be wise to spend one winter or spring term (on the basis of three terms per year) almost entirely on cookery; laundrywork too, will benefit if it can be studied and practised intensively over a period of a term or half a term, and for this the summer term is advised in view of the obvious advantages of the out-door drying of clothes. But the teacher should always remember that the final objective of the teaching is to enable girls to carry out the work of a home, even though that home be only one or two rooms. It seems probable (and indeed the writer believes it has often proved to be the case) that highly-intensive specialized teaching of cookery and laundrywork has divorced a girl's interest because much of the work could not possibly be carried out in any home with which she was familiar and was quite remote from her own experience of life.

Again, towards the end of school life housecraft will no doubt merge into a study of mothercraft, and girls will spend their time in considering the needs of infants, toddlers, and of others whose welfare is in the keeping of the mother. Clothing, feeding, bathing of babies and small children cannot be carried on as isolated pieces of work, but must be arranged or organized as a whole, together with the ordinary daily duties of a home.

This complex business is sometimes described in educational terms as "home-organization," and demands applied intelligence and careful training. It is perhaps at this stage that a teacher can best judge her own work, and gauge the extent to which she has attained the aim with which she started, namely the maintenance of well-being, health and happiness in the community, while developing habits of self-reliance and dependability in the pupils.

Experience shows that while it is not possible to draw up a completely logical set of lessons in such a complex subject, teachers should not overlook the manifest advantages of treating certain allied aspects of the work on as logical a basis as possible—e.g. the use of foundation mixtures from which many varieties of cakes and puddings, etc., can be made. *The High School Cookery Book*, by Miss Grace Bradshaw, published by Longmans, Green & Co., gives a number of these "foundations."

It is wise to make a list of points which should receive attention, and on which definite teaching should be given. The following suggestions for such a list are in no sense exhaustive.

Cleansing Processes

(*a*) *Personal Hygiene*

Early lessons on simple cleanliness of hands, hair, etc., will lead up to the hygiene of adolescence, to simple instruction about the body and its functions and finally to infant welfare and mothercraft.

(*b*) *The Cleanliness of the Home*

Here again the early lessons will be simple, and should deal for the most part with household utensils and their care. Cleaning and polishing agents for wood, metal, etc., will be made and used. In later stages care and cleaning of rooms, their fittings and furniture will be included.

(*c*) *Laundry Work*

Correct methods of washing and finishing various fabrics.

The hygiene of clothing.

Value of fresh air.

Composition of soap powders, starch, etc.

(*d*) *Civic Hygiene*

Dustbins, refuse tips. Water supply. School medical service, hospitals. Infant welfare centres.

The Nourishment of the Body

FOOD

(*a*) Its selection and storage;

(*b*) The arranging of meals to suit differing needs, occupations, and means;

(*c*) The preparation and serving of cooked dishes and meals;

(*d*) Quantities and costs in relation to family income or sum of money available;

(*e*) The consideration of cooking in bulk as for Sports Teas in school, restaurants, cafés;

(*f*) Food values; dietetics;

(*g*) Preservation of foods, bottling, pickling, jam-making, storage of eggs, etc.

III. Methods of Teaching

Practical subjects make heavy demands on teaching skill. Each teacher should therefore consider carefully on what lines she intends to teach.

It is of first importance that adequate time should be given to practical work by the girls themselves. The Board of Education in the *Handbook of Suggestions for Teachers* lay great stress on this point. Many girls will have already had some experience of domestic duties in their homes—where this is good a teacher can build on it; where it is less good she must prove convincingly by the results of the work she herself does that there is a better way of working. It should be the aim of every teacher to enable her scholars to undertake a piece of work, whether cooking, cleaning, or washing, with the minimum of help and the maximum of self-reliance, and to produce reasonably good results.

Lines of Approach

In many schools science is being taught in close relationship to housecraft and affords a clearly educational line of approach. If the housecraft mistress also undertakes, as she well may, some science teaching, the problem is comparatively simple, for she will relate the housecraft practice to the work on air, water, biology, etc., done in the science lesson. It may frequently happen that there is a science specialist on the school staff, and that the housecraft mistress has not time, or is not required to teach science. The fact will remain however that many of the practical applications of science must be worked out in the kitchen or laundry. The teacher should therefore work in close collaboration with the teacher of science and plan a scheme which will make the best possible use of knowledge gained in the laboratory.

In mixed schools during the first two years, girls and boys are often taught together by a science master. This need not necessarily limit the possibility of collaboration, but may make it less easy to plan a scheme suited to all the interests concerned. It might be possible to devote a part of Year I to science as set out in *Elementary Science for Domestic Teachers*, by Hilda Shaw, B.Sc., in schools where there are no facilities for laboratory work. Girls have much enjoyed carrying out these experiments in the kitchen or classroom, and if later they have proceeded to the laboratory they have been found to work with greater precision than girls who went there direct.

A Suggested Allocation of Time

There will be many cases where the teacher is fully occupied with classes in general housecraft (simple housewifery, laundrywork, cookery and perhaps home organization) and a suitable division of time must be made. In no case should the division set out below be taken as final, rather should it be considered by each teacher in the light of her known limitations and opportunities.

If the total number of hours available is under three hundred (300) the last section of the work must be omitted, or certain parts of it which are essential, such as infant care, should be retained and some of the time given to laundry work or cookery be sacrificed.

The type of school and its bias, together with the number of housecraft rooms and other equipment, will determine the number of hours which will be allotted. It is safe to assume that the time will never be less than 250 hours during the three years' course nor more than 450 hours.

	Yr. I	Yr. II	Yr. III
SIMPLE HOUSEWIFERY	Hr.	Hr.	Hr.
The home and means to keep it clean and bright. Uses of water, soap, and other cleaning agents. Preparation of polishes. Care of utensils and equipment, e.g. stoves. Floors and floor coverings. Furniture, brushes, and their care. Lighting the house. Windows, mirrors. Care of silver and glass. Setting tables for meals	18	20	
LAUNDRY WORK			
Equipment and utensils, their choice and care. Water supply. Washing—white and coloured cotton goods Ways of finishing. Woollens, silks and their suitable treatment. Laundry materials—selection and storage. Soap-making. Stains. Care of table linen, curtains, lace. Treatment of velvet, chamois leather gloves, eider-downs. Simple dry-cleaning . .	12	25	35
COOKERY			
Methods of cooking vegetables, meat, fish, puddings, cakes, pastry. Soup-making. The work food does in the body. Vitamins. Marketing. Family meals. Storage of foodstuffs. Preservation of food. Foods for infants, invalids	10	55	65
HOME ORGANIZATION			
Daily, weekly, and periodical care of rooms, furnishings, etc. Household washing. Clothing: its care, cleaning, repair and renovation. Economical expenditure on meals, and other household supplies. Keeping of household accounts. Mothercraft, infant and child care. Preservation foods, jam-making. Storage of eggs, etc. Cooking in bulk for family or business purposes. Planning of diets. Household repairs and odd jobs.			65
	40	100	165
Grand Total	305 hr.		

Demonstration

In the early stages of domestic teaching time should be given for simple, clear demonstration. Having regard to the immaturity of the first year pupils, and to the great complexity of the subject-matter, demonstration should deal with certain definite methods or principles, or aspects of the work, and not attempt to cover too wide a field. For instance, in an early laundry lesson on the washing of pillowslips the handling of the goods is important, so too is the order in which the various processes are carried out. These two matters should be stressed in the demonstration, and desultory instruction on suitable soaps, or various methods of drying, etc., be severely excluded until a suitable opportunity arises. This may be at the end of the lesson or at a special lesson on methods of drying, or perhaps in the case of soap at a science lesson. No good teacher should feel that she ought to talk throughout the entire demonstration. If her manipulation and technique are good the girls will be interested to watch her working, and are almost certain to learn good methods more quickly when they concentrate in that way. On the other hand, it is certainly wise at suitable times during the lesson to recognize and discuss links with other work done in school or at home. A clever teacher will quickly find that housecraft is related to almost every "subject" in the curriculum, including history and geography, but perhaps especially linked with science and art. There are many household processes which by their nature cannot be completed in one continuous period and which lend themselves to what might be described as demonstration by stages. Bread-making, soup-making, and many cooking processes come into this category as well as almost all the laundry processes. The teacher will make the most of these opportunities and work with the class, giving brief, clear demonstration of each stage, at the apt moment.

As time goes on it is often wise to reduce the time for class demonstration to a minimum, always taking care that individuals are shown correct methods according to their needs. It will be constantly necessary to give repeated demonstration on technique. Manual skill in carrying out processes certainly affects the result, as well as saving time and effort, and every endeavour should be made to secure it. But demonstrations of this sort should perhaps be given another designation, for when well done they are usually quite brief, but carefully directed to a specific point in management or control of media.

IV. *Plans of Work*

Having arranged what ground she hopes her pupils will cover during their school life in view of the facilities and time available, the teacher should proceed to prepare a plan for each lesson. This plan will probably differ in many ways from the notes of lessons which she has been accustomed to prepare while in College.

It will show among other things what time is set apart for demonstration, and how long is to be devoted to practical work by the class, whether note-making is to form part of the girls' work, and what share of the general work of the housecraft room each pupil will be expected to undertake. There is a possible danger in these plans and paradoxically the more complete they are the greater the danger, unless the teacher also expects from each girl an individual plan. It would probably be agreed that even in the earlier lessons on laundrywork, or cookery, where the girls work as a class no two girls are found to tackle their whole morning's work in precisely the same manner. There is a very strong case for requiring from each girl, at every lesson, a plan of the work she is going to do. If this is expected from the first, when the lesson period is short, and the work probably straightforward, the habit can be formed, and in itself will prove a valuable part of education. A teacher who decides to accept this suggestion will find that it is desirable to inform the girls what their work will be a week ahead. Then, if it is not possible to get the plan made at home, the first ten or fifteen minutes of each lesson should be devoted to its preparation by the girls and correction by the teacher. So useful is this piece of work that it might quite justifiably replace the "notes," which are sometimes of far less practical value.

In this connection it is possible to borrow an idea embodied in a method known as the Dalton Plan and modify it to serve the needs of practical work. The teacher should prepare a series of cards on each of which certain pieces of work are set out. The cards may be in triplicate, or even larger numbers, so far as the main topic of the lesson is concerned, but varying in the extra duties which must be undertaken in order to keep the room and its equipment in order.

Examples of such cards are given below. When complete the series should cover the entire course in housecraft.

Housewifery, Year I. Term I

Card 3 (*a*)	Card 3 (*b*)	Card 3 (*c*)
Clean a pair of shoes. Dust and tidy the pantry shelves. Answer the question written on the blackboard.	Work out the two experiments on leather which are written on the blackboard. In your notebook write down what you observed in each experiment. Clean a pair of shoes.	Clean a leather attache case or handbag. Wash out two dusters. Read up all you can find about leather in the dictionary or encyclopædia, then write two or three sentences about it in your notebook.

Cookery, Year II. Term I

Card 10 (*a*)	Card 10 (*b*)	Card 10 (*c*)
Make a steamed suet pudding and jam sauce. Draw in your notebook sketches of two or three ways in which steaming can be done Wash up all utensils. In the text book read all you can find about suet and its uses.	Make an apple pudding and custard. Wash up all utensils. Tidy the store cupboard. Write out a list of all the puddings you know for which suet is used. Work out the cost of the pudding.	Make a rolypoly pudding. Bake apples. Clean sink A. Answer the questions on the blackboard in your notebook. Dust all window sills. Give prices of each food-stuff you use.

The first set shown above would come in the first term's course of work; the lesson being an hour or slightly longer. The second set would come during the first term of the second year, when the lessons are usually of 2½ hours duration. In both these cases the core of the work is similar, and one or other of these three cards would be worked by each girl in the class in turn.

In addition to planning the work set, each pupil must enter up in her notebook a copy of the card given her for the next lesson. There will also be a short demonstration, or other form of class teaching during the lesson period. If a girl's practical work is quite a failure, she can take a second card of the same series and repeat the main work at the next lesson if the teacher thinks fit. In actual practice there are times when some of the quickest pupils may be working ahead of the demonstrations. This is no objection, as girls who are readily able to interpret recipes and written instructions for themselves are most likely to profit by good demonstration whenever it may be given.

The teacher will be interested in reading *Science in Senior Schools*, p. 31, paragraph 26, which deals with the question of doing practical work from cards. This book is published by the Board of Education, and the price is 1s. 3d. It can be obtained through any bookseller.

V. Aids to Teaching

The teacher will find that she needs large numbers of concrete illustrations with which to interest the children. Among these will be—

1. Drawings and pictures of foodstuffs, their production and treatment, in preparation for sale. The Health and Cleanliness Council and the Dental Board of the United Kingdom publish interesting posters, which are to be had at a small cost. The collaboration of the art teacher will be of great value here, as well as in matters of home decoration, furnishing fabrics.

2. Samples of dry goods used in household processes, cleaning, cooking, etc. The teacher should bear in mind that to many of her young pupils even such simple things as lentils or beeswax are strange commodities and afford a stimulus to their minds if rightly treated. Many of these can be chosen as samples and stored in small glass bottles, carefully corked and labelled. This is a better plan than taking a specimen from the ordinary supply (especially if the item is to be used for cooking) as the children can see it perfectly, but need not touch it.

3. Specimens of fabrics of every kind, their source, manufacture, and condition before and after treatment in the laundry. These can be mounted and labelled and covered with cellophane paper, to permit of free handling by the scholars.

4. Illustrated catalogues can readily be obtained and are of help in many lessons. They can be had in great variety dealing with almost every aspect of the home and its equipment. Curtains, carpets, kitchen ware, and household furniture, means of heating and lighting are all subjects for advertisement by those who wish to sell them, and if a catalogue cannot be obtained the daily Press supplies large numbers of illustrations of advertised goods.

5. The girls are often greatly interested if they are encouraged to bring cuttings from the papers dealing with the work of the day which can be pasted into a book for future reference. This scheme can be used to benefit every grade of intelligence, as the quick stream pupils can index the book and render it a valuable property, while the slower girls can enjoy the preparation of the book (which can be usefully made from strong brown paper in schools where bookcraft has no place in the curriculum), and sorting and pasting-in the contributions. Such a book has been known to provide the stimulus which made the entire work at a housecraft centre vital. Breadth of interest has been given in another school by the collection for such a book of pictures showing homes and families of other countries.

6. Many teachers use models of household apparatus, and fittings. For example, small working models showing the various means of ventilation can be made, another working model often seen illustrates the hot-water system found in many houses. These and similar models can be prepared by the teacher and scholars from simple inexpensive materials.

7. Specimens of brushes, and the materials from which they are made, can often be obtained from manufacturers. Travellers' samples of such things as linoleum, and other floor coverings, of wall-papers, curtain materials, etc., are useful and can usually be readily obtained from local shops at little or no cost.

VI. Books

There should be books of reference in every housecraft department. A library could be built up gradually and should contain simple recipe books from which the girls could work, as well as pamphlets and books dealing with one or other of the branches of housecraft. Some of the books should be sources of definite information, and not merely give instruction as to the carrying out of various processes of household work. Textbooks on hygiene, physiology, electricity, will be required, as well as books on the technique of laundry work, jam-making, and other specific aspects of practical work. There are to-day many publications dealing with women's interests, and it is often useful to have a supply of lighter literature which can be at the free disposal of girls who may be waiting for a garment to dry before ironing, or a dish to finish cooking, and where such magazines and papers are available, no girl need have a vacant mind.

A list of useful books will be found at the end of this section. No claim is made that the list is comprehensive, but the books therein are known to the writer and their value to teacher or pupil or both has been tested.

Notebooks

Suggestions have already been made in the text as to the use of notebooks. If these are followed no teacher is likely to revert to a bygone system of copying notes and recipes from the blackboard—work which made little or no demand on the initiative or intelligence of the pupils.

Plans of work, results or comments on tests and experiments, sketches (e.g. how milk may be kept cool in summer) are all suitable for inclusion, provided they arise in the normal course of experience.

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Science of Common Life, by Simmons and Stenhouse (Macmillan, 3s. 6d).

Electrical Housecraft, by Kennedy (Pitman, 2s. 6d.).

Physiology for Beginners, by Foster & Shore (Macmillan, 3s.).

Elementary Science for Domestic Teachers, by Hilda Shaw (Pitman, 3s. 6d.).

Practical Laundrywork, by Wetenhall (Pitman, 5s.).

A Laundrywork Notebook, by Wetenhall (Pitman, 1s. 3d.).

Practical Courses in Housecraft, Edited by E. Jardine (Methuen & Co., 3s. 6d.).

The Smokeless City, by Simon & Fitzgerald (Longmans, Green, 1s. 6d.).

Housecraft Principles and Practice, by Binnie and Boxall (Pitman, 8s. 6d.).

The A.T.D.S. Cookery Book, The A.T.D.S. Laundry Book, The A.T.D.S. Housewifery Book, issued by the Association of Teachers of Domestic Subjects, 33 Gordon Square, London, 1s.

Vitamins and Choice of Food, by Plimmer (Longmans, Green & Co., 7s. 6d.).

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Cooking Craft, by S. E. Nash (Pitman, 8s. 6d.).

Domestic Handicrafts, by M. H. Murray (Pitman 4s.).

VII. Other Responsibilities

There are many responsibilities which devolve upon the housecraft mistress in addition to the actual teaching side of her work. It should be said at once that some of these can be used in the training of the scholars, and will help to deepen their sense of the importance of the work. But even so, the teacher is the responsible person. Some of these duties may be considered as belonging to the administrative sphere, and if she is on the school staff she will have the guidance and support of the head teacher.

Equipment, Stock, and Stores

It is probable that the housecraft mistress will be definitely responsible under the head teacher for all the equipment in her room. It will be necessary once every year to enter particulars of the stock in a book which the Education Authority will provide and which must be available whenever required, for the purposes of audit. There will be columns for articles received and articles consumed, missing or transferred, during the period under review. A wise teacher will check the stock at frequent intervals, and a simple way to do this is to prepare lists of items of a similar sort, and check some of the lists each week. Unless great care is exercised, stocktaking can become an awe-inspiring and depressing task, but if good general oversight is maintained all through the year it need cause few fears.

Equipment for domestic subjects, as, indeed, for all practical work, is of so various and costly a nature that it requires especial care.

EQUIPMENT OF A PERMANENT NATURE

The permanent equipment, such as cooking stoves, wash boilers, washing machines, etc., should be kept in perfect working order. It is often possible for small repairs to be done without the help of a tradesman, but any injury or fault which is likely to put a piece of apparatus out of commission should be reported at once to the head teacher or the Local Education Authority.

The lubrication of machines should be a matter of regular routine as it is in a well-managed home, because neglect may cause considerable expense.

LOOSE EQUIPMENT

In this, cupboards and other furniture may be included (see General Considerations, Note 5), as well as crockery, cutlery, hardware, linen, brushes, books, and stationery. These all require care if they are to be kept in good condition and suitable for long use. Much of their care is incorporated in the course of instruction, but the teacher must keep a firm check on the condition of the articles, as well as on their numbers, correct use, and storage. It is certainly not an economy of time or energy, and only doubtfully of money, to continue to allow girls to practise with blunt knives or out-worn brushes, etc. The teacher will therefore be wise to have in use only the numbers of each article which are essential, and she will endeavour to keep an adequate number in reserve. By this kind of careful management, the girls will learn one of the first principles of home organization, even if the housecraft course only runs through two years of school life.

The towels, tablecloths, and other linen should be clearly marked according to their purpose, and stored in a suitable place. Stationery, pens, ink, and pencils will all be needed for use in the housecraft room, where inkwells often prove a menace. A square wooden stand can be made which has a hollow centre into which the inkwell fits. This is said to be a simple piece of work for boys learning woodwork, and is of great use. The girls are found to take a pride in the care of things which have been made for their use, and in one large Senior School, known to the writer, have painted the inkwells and other wooden equipment which could suitably be treated with paint, in the House colours.

REQUISITIONS FOR ADDITIONAL STOCK

It is the duty of the housecraft mistress to prepare lists of stock required for the maintenance of the standard equipment. The Local Education Authority fix dates on which requisitions will be received, and the head teacher will send in the official form, from the particulars supplied to him or her by the specialist. The list should be discussed with the head teacher, who will doubtless be able to give guidance on doubtful points. Some authorities have a standard list of equipment (this is frequently a list that has been approved by the Board of Education) and little or no divergence is encouraged. In other areas a large degree of freedom is allowed which, while adding to the teacher's responsibility, may enable her to treat her subject-matter from a wider point of view and give increased opportunities for varied practice by her pupils.

If the domestic work is carried out at a centre the mistress will need to take entire responsibility for all the stock and stores, requisitions, and other administrative matters.

Material for Class Use

There is a further aspect of stock which the teacher will need to consider—the material for class use. This falls into two main categories—

(*a*) Household stores, such as soap, starch, salt, baking powder. Also simple First Aid equipment, sewing materials, etc.

(*b*) Perishable goods, such as meat, milk, vegetables, etc.

It is customary for dry goods, particularly materials for cleaning and laundry work, which can safely be stored, to be ordered by requisition, but in some districts the teacher is authorized to obtain from local tradesmen the goods she requires.

Perishable goods should be selected daily by the teacher and scholars. Groceries and goods which can be kept without fear of contamination for a reasonable length of time can be ordered once or twice per week.

In the country, and semi-rural districts, and probably in towns, too, where there is a school garden, it will be possible to get supplies of vegetables, eggs, and other commodities at a cheap rate. Where the housecraft mistress has established happy relations with the parents she should have little difficulty in getting them to provide food materials for cooking. The meals prepared will then be adequate for a family and a frequent source of criticism be removed, namely, that the small quantities used for practice render the work of little value.

The mistress will need to use considerable foresight in planning the work of a class, if each pupil is to get her fair share of cooking accommodation without undue crowding or overlapping. She will be wise to arrange a rota of girls showing clearly on what dates and at which piece of apparatus each will be working. It should be possible for each girl to have experience in managing the cooking stoves available, and to learn to use fuel, whether oil, coal, coke, gas, or electricity, to the best advantage.

If laundrywork is to be taught and practised a good supply of articles will be needed for each lesson. It is not usually difficult, provided the teacher is tactful, to get the girls to bring clothes, etc., from home. The school equipment can be drawn upon if supplies fail, and it is often a boon to a junior or infants' department if help can be given in housecraft practice towards keeping work-bags, lunch-bags, floor rugs, etc., in good clean condition. Usually the girls are most willing to bring small articles from home for cleaning lessons, e.g. silver-plate, shoes, pictures, small carpet rugs, and a clever teacher will make good use of this as a means of enlisting the mother's help and interest.

Accounts—Cash Book, etc.

Accounts for equipment and goods ordered in accordance with the teacher's requisition will be settled by the Authority, but it is necessary for the teacher to certify that she has received the goods and that the accounts are correct and the charges reasonable, and the materials, etc., of suitable quality. The usual plan is that a printed form of acceptance is signed by the teacher and forwarded to the Education Office with the invoice which accompanies the goods on delivery. Accounts for goods which the teacher herself orders she is almost invariably required to settle. Much of the cooked food, as well as some other products of the housecraft classes, such as cleaning agents, polishes, floor-cushions, will be sold to the children. Therefore a cash book showing sales and expenditure must be kept. Education Authorities adopt a variety of methods by which they require housecraft teachers to keep clear accounts suitable for production to the Government auditors, and it can safely be assumed that teachers will be given the requisite rules and information. Many authorities make an advance of £1 or 30s. to each teacher to cover initial expense, and then expect that monies received for sales will be available for further expenditure. Some authorities make no initial advance, but refund to the teacher at certain stated intervals any loss she may have sustained. The utmost care should be exercised to keep the accounts with accuracy. Receipts should be entered daily, and it is generally advisable to pay the tradesmen's accounts not less frequently than once a week, when they, too, should be entered on the opposite page. The smaller payments should be entered on the date they are made. For the purposes of audit all receipts must be produced; the teacher should therefore get a receipted account for all monies paid. The simplest way so far as the main accounts are concerned is to have a book for each tradesman—butcher, grocer, fishmonger, greengrocer, and milkman—this will show every detail of the transactions—weights, dates, prices, etc., and further, it can easily be checked. There are, however, other considerations besides those of audit which no good teacher will forget. She will want her pupils to have practice in the selection of foods; she will require a measure of freedom to buy in bulk when prices are low. The dated, receipted, account should make this kind of buying possible, while the milk book, grocery book, etc., enable her to give the girls an insight into a more routine means of recording purchases.

Records of Work

Whilst there is much good reason for the opinion that the girls' notebooks are the best records of work, few teachers will agree that any just view of their efforts can be gleaned from such a source. It is most difficult to keep an honest record of work, and it is unlikely that any teacher does herself justice by a formal record. She will, however, be required to keep a record in some form or another, and should take pains to prevent it from becoming too stereotyped, a mere list of dishes made, or processes taught. It would be well to include in the record a note of any method of treatment which proved successful, of any experience which aroused special interest.

Log Books

Teachers working in centres will probably be expected to keep a log book. This is quite different from a record of work. Entry should be made of any matters likely to be of historic interest so far as the fabric and its fittings are concerned. Notes of visits received from His Majesty's Inspectors, members of the Local Education Authority, etc., should be entered, together with a copy of any report that may be received on the work. Dates of holidays, closures, changes in staff, modifications relating to the use of the building or extensions of its use, educational visits and journeys should all be noted in the log book.

Educational Visits

However short a time is set aside for housecraft during the years of Senior School life, some of it should be spent in visiting one or more places of especial interest, such as a canning factory, modern dairy farm, waterworks, infant welfare centre. Urban schools will more readily find facilities than rural schools for such visits, though it is becoming increasingly simple to convey parties of children from the country to places of interest; indeed in many areas manufactories of all sorts are to be found, in the country as well as town.

Further Responsibilities have sometimes to be met in that certain schools arrange to exchange boys' and girls' classes for practical instruction. The woodwork master gives a short course in the use of tools to the girls, while the housecraft mistress teaches simple cookery and housecraft to the boys. This is very interesting work and has often produced excellent effects.

Personal cleanliness and simple processes in cooking and washing are the main aspects of this teaching for which usually only a limited time is available.

Another further responsibility which teachers are undertaking in many places is the supervision of school meals. Where it can be done without jeopardising the work of teaching, there can be no doubt as to the inestimable value of trained supervision. Any teacher of housecraft who can conscientiously help in this matter will discover its immense influence on the manners and tone of the school. It is a piece of social work well worth undertaking.

VIII. Evaluation of Progress

MARKS, EXAMINATIONS, REPORTS

It is necessary for the teacher to have a clear idea of the progress being made by each of her pupils.

The system under which marks up to a definite maximum can be earned has long been in vogue. To-day many schools are experimenting with less arbitrary methods of evaluation, calculated to encourage the team or school spirit rather than to assess individual merit, always a difficult and possibly dangerous undertaking. These methods appear to be sound so far as they have been tested, and in many schools the housecraft mistress will be required to assess the work of various groups of girls according to the plan adopted by the head teacher for general use in the school.

The old system of giving marks became somewhat discredited in the eyes of many teachers because it gave a child the idea of a destructive rather than constructive attitude towards its work. Marks were "lost." Under one Local Education Authority a plan was put into operation at a housecraft centre, whereby every member of a class started equally with nothing—0—to her credit. At the beginning of a lesson certain general rules if obeyed each gave one "credit" towards a total which was never defined. In this way girls were encouraged to bring aprons, caps, materials for practical work, etc. During the lesson "credits" could be earned for such things as a sound plan of work, good practical results, order and method in work, economy of fuel, written work, any notable expression of common sense, etc., etc. Each pupil kept a list of "credits" earned as did the teacher, and at the end of a period of two or three weeks, a "growth" chart was filled in showing how many "credits" each girl had earned. Squared paper was used for these charts and each square was the equivalent of five credits. The girls were greatly interested in this method of expressing progress. Several plans of a similar kind have been tried, usually with good effect on interest and effort.

PROGRESS CHART

SPRING TERM, 1936

*Class : Year I*B

A. Brown	C. Dixon	E. Foster	G. Heath	I. Jones	K. Lane	M. Nixon	O. Pratt	P. Robson
							×	×
			×	—		—	×	×
×	×	—	×	—	—	×	—	×
—	×	×	×	×	—	×	×	×
×	×	×	×	×	×	×	×	×
×	×	×	×	×	×	×	×	—
×	×	×	×	×	—	×	—	×
×	×	×	—	×	—	×	×	×

Names.

| means absent.

EXAMINATIONS

A practical subject such as housecraft does not lend itself to ready assessment by examination. Yet it is necessary from time to time for the teacher to set papers and practical tests in order that the work may take its place on the school reports. It would be well if an

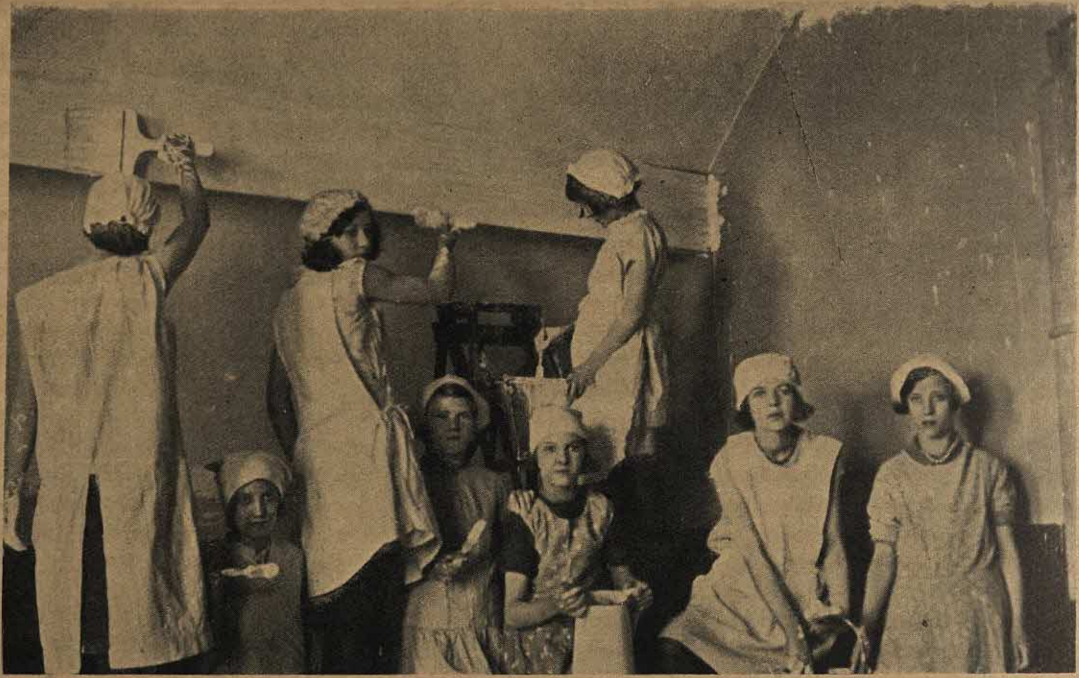
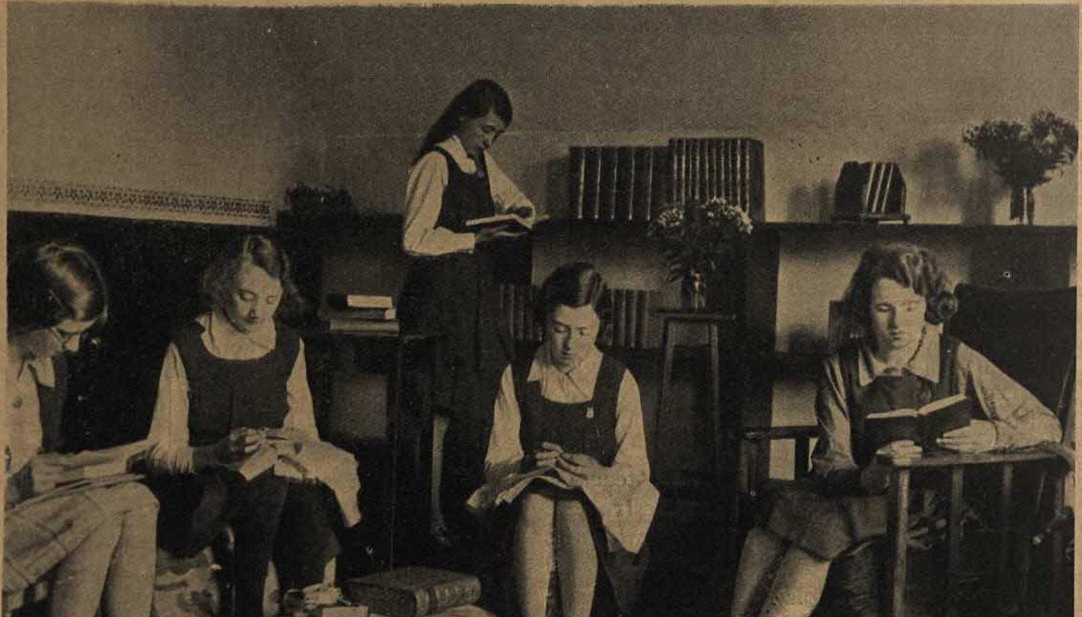


FIG. 1

A Lumber Room, with Pupils at Work Transforming it into a Library Study



Photographs by courtesy of *T. Lowe, Head Master of a Senior Mixed School in Stoke-on-Trent*

FIG. 2

The Library Study in Use

examination were given only once, at the end of each year, instead of each term as is often the case.

The questions for a written examination should be expressed in simple words, and be capable of a direct answer, since it is knowledge of housecraft and not composition that is being tested.

Practical tests should be carefully planned to give each girl a fair share of the stove and sink accommodation which is available. If the girls are accustomed to earning "credits" it should be possible to "mark" the practical examination on similar lines, but fixing a maximum with which all start, and making it quite clear to the examinees that marks will be "lost" for bad plan of work, poor results, lack of order and method, lack of common sense, lack of general economy, etc. There is much yet to be learned about the technique of examining, and the suggestions given above are so imperfect that the writer can only hope others will be stimulated to explore the possibilities of this side of school work and find better methods which will do greater justice to scholars.

Reports

The teacher will find her record of credits a great help in making reports on progress. If, in addition, she has before her the girls' own note books she can form a clearer judgment of what progress has been made, and a fairer estimate of the causes which have made for failure or success. It is conceivable that in writing out these reports the teacher may see where she herself has succeeded or failed and thereby gain valuable experience for future work. The writing of reports appears to be a necessary, but is certainly not an easy task.

IX. The Rural Area

The foregoing paragraphs have dealt for the most part with urban or semi-urban areas, and no special mention has been made of conditions prevailing in many rural districts. There is the problem of the country school. Certain L.E.A.'s endeavour to meet such cases by providing well-equipped vans which, in charge of qualified teachers of Housecraft, travel throughout their districts, staying for a month or more at selected villages. Much interest is aroused by the presence of the itinerant teacher and the van. Yet one must recognize that in these circumstances the contribution to the main body of education in the school can only be passing, though sound work is no doubt done. As a contribution to rural social life, however, this method has much in its favour, and the value to the older members of the village community should be borne in mind.

In other districts a keen and interested teacher may, though possessing no specialist qualification, devote some period in school time to the needs of the oldest girls. Cookery, cleaning processes, and mothercraft may be included according to the knowledge and interest of the teacher and to the facilities available in the school, or, perhaps, in the school-house. This appears a useful way of making the work an integral part of school life, and, provided there are reasonably good conditions, probably few rural schools could not do something for themselves in this informal but frequently most effective way.

The writer has known such schools where the work has been beyond praise, and any teacher who undertakes Housecraft teaching in this simple way may reap for herself, and for many of the girls in her charge, a thoroughly happy harvest in the future life of the rural community.

The numbers of Senior girls in a rural school would not be large, and the simple conditions would lend themselves to reality of work. Individual and group responsibility would be emphasized by force of circumstances. Difficulties would present themselves and require solution, and in this way, working under conditions not, perhaps, ideal in themselves, opportunities for training judgment, imagination, and resourcefulness would frequently arise. In the less sophisticated surroundings of a rural school it is possible to carry out many of the essential interests of the home with great advantage to the general education of the children.

INFANT AND CHILD CARE

Aim in Teaching

WITH all teaching, the aim or ultimate end should be borne in mind. Every school girl or boy must be turned into a useful citizen, and the information she or he receives at school helps to achieve this object. A knowledge of Life, and how to meet its many emergencies, is the backbone of education, and all subjects should have this aim before them. The modern girl, on leaving school, will find many avenues open to her; she is not in the position of her Victorian ancestress, whose only recognized place was in the home. In spite of this advancement, however, the Home, quite rightly, still plays a very important part in our national life, and the greater proportion of the girls leaving the Senior Schools of to-day will be required either to manage or to assist in the management of a home.

Value of Home Life

The primary reason for the Home is the security and safety of the child, because it has been realized that the Nation's future depends obviously upon the coming generation. An A1 nation depends upon A1 babies, and, to achieve this end, A1 parents are needed. The present boys and girls are the future parents, and therefore any education they receive will be lacking if it does not include definite preparation for this most important part of their citizenship. Many of the tragedies, and the appalling wastage of human life, would be avoided if knowledge could replace ignorance.

The subject termed Infant and Child Care is often misunderstood. It has been described as Applied Hygiene, and this is one of the happiest explanations that could be given. Unless the pupil has a sound knowledge of the principles underlying healthy living, it is impossible for her to understand any study of Infant and Child Care; but, with this necessary previous knowledge, she can apply it, under guidance, to the special study of the baby and toddler; and prepare herself for Life in a sane and normal way. Much of this preparation is unconscious, but will bear fruit eventually in the healthy homes of the future.

Every school curriculum should include Hygiene in the time-table from the Infant Department upward. In the early stages, it will take the form of Health Talks, and the establishment of healthy habits, leading gradually to definite instruction based upon the processes of life. This instruction will be continued in the Senior School, probably as Biology, branching finally into Communal Hygiene for the boys, and Infant and Child Care for the girls. Thus is the early knowledge directed into channels where it will bear most fruit. The woman will generally apply it to the management of the home and children, and the man to the needs of the community—by insisting on right sanitation, correct protection of food and food-stuffs, sound and proper buildings, etc., he will protect his own home and family from disease and ill health.

The Junior Foundation

The Senior School will be fed by the Junior Schools, in some cases two or three schools, and in other cases many more. The former will occur usually in towns and cities, and the latter in the rural areas. However many Junior Schools feed the Senior School, it is essential that the right foundations should be laid in all if it is proposed to include Infant and Child Care in the Senior curriculum. Conferences between the Heads and Staff of all schools concerned are not only beneficial but absolutely necessary. This will prevent waste of time by overlapping; it will mean that all the children start in the Senior School with the same elementary knowledge in Hygiene, and that the Senior teacher need waste no time over preliminaries. It will be seen later that the subject under discussion embraces many other subjects, including Needlework and Handwork, and therefore a sound foundation in both these crafts is needed by entrants to the Senior School. The Senior Schools will need to deal tactfully with their contributary schools. To dictate schemes and syllabuses to them would be a foolish and narrow policy; rather, they should give them an understanding of what knowledge they will expect the children to have acquired before passing from the Junior to the Senior stage, and leave the schemes and methods of imparting that knowledge, so far as Hygiene, Needlework, and Handwork are concerned, to the discretion of the Junior staff. The Senior School should be supplied with the schemes that have been employed, and also with details of the pupils' progress.

PLANNING THE COURSE

The planning of the Infant and Child Care Scheme depends upon many things, and therefore it is impossible to give a syllabus which would fit any and every school. The main points for consideration are—

1. Locality.
2. Type of School.
3. Staff.
4. Subject matter.

Locality

The Senior School may be situated in a town, in a good residential area or in a slum area; it may be in the country; or in a small rural town. This means that the teacher in charge of the Infant and Child Care course should have a knowledge of the home conditions of her pupils. This is essential with a subject which deals directly with the home. It is useless to talk of nurseries and nursery equipment to the child who dwells in one or two rooms. The teaching must be based upon the circumstances and methods of living that the girl will understand. Little ways of improving existing conditions, of making them more attractive and habitable, will be understood and appreciated. Suggestions which are unpractical, due to the expense entailed, may form delightful daydreams to the imaginative adolescent girl, but, because they are so unobtainable, they form no standard for her, nor do they help with her immediate problems. Such teaching may do harm to a certain type of child by causing dissatisfaction. The teacher needs an insight into the ordinary everyday life of the child, and, if this knowledge cannot be obtained, the subject should not be included in the curriculum.

Some form of definite instruction for teaching is necessary, and several Training Colleges are including a course in Infant and Child Care in the training. If the would-be teacher has not obtained this instruction during her training, she should endeavour to obtain it elsewhere. Summer Schools are held, dealing with the subject, and there are also Nursery Training Schools and Colleges which run vacation courses. Evening Classes are organized in some towns. Where it is not possible for the teacher to take a special course, she should read the latest books on the subject, and become familiar with the modern methods. In any case, whether trained or untrained, she should get to know the School Nurse and the Health Visitor for the area if there is one. Much useful information on the home conditions can be obtained from these sources. The Maternity Nurse, too, can be a mine of information, but it must be borne in mind that it is of the healthy normal baby that knowledge is required. Nothing that is abnormal should enter into the teaching of this subject. The whole object of including it in the curriculum is *prevention* of disease and ill health. The sick baby is a problem for doctors and nurses, not for the school girl. In most cases the School Attendance Officer can give invaluable help in describing the homes he visits, and every means of ascertaining this knowledge should be sought by the teacher.

Sometimes visits to the homes on Saturday mornings can be arranged with the Health Visitor; visits could perhaps be arranged during the holidays; and leave might be granted by a far-seeing Education Authority for visits during school hours.

If there is a local Welfare Centre, it should be visited, and the methods employed carefully studied. It is essential that all instruction given to the mother in the Centre and to the child in school should be on the same lines. Contradiction means disaster. It is a subject upon which there are widely different points of view, and therefore co-operation is most necessary.

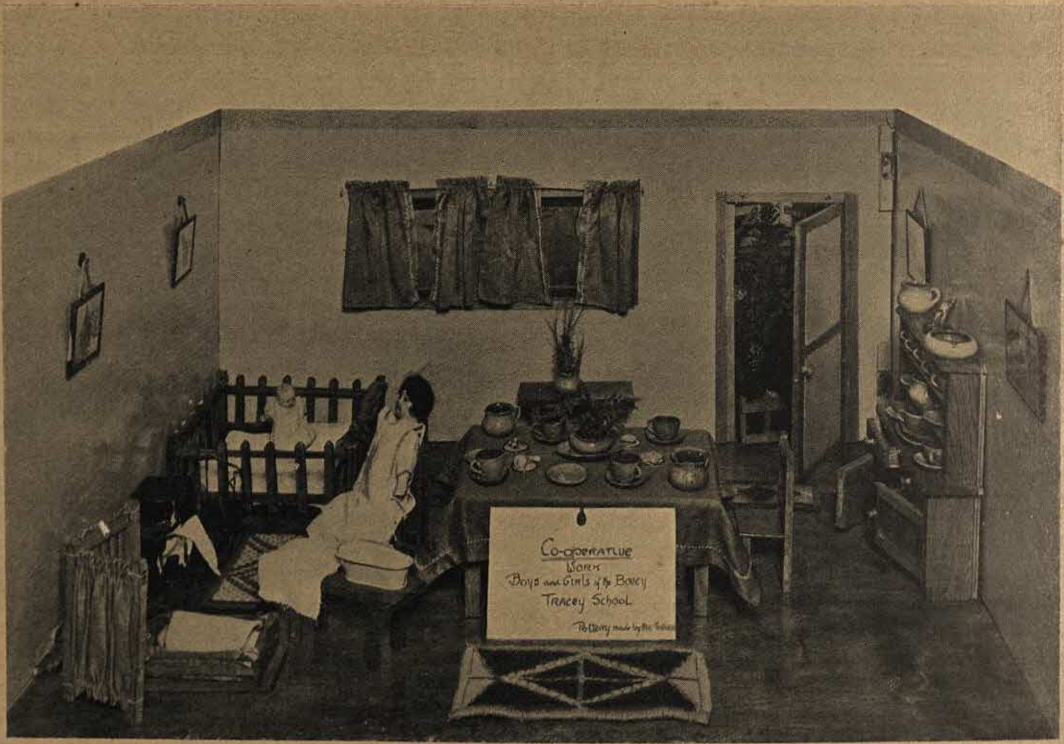


FIG. 1
Co-operation between Boys and Girls

Type of School

Under this heading it is necessary to consider two types only—the new Senior Mixed School which will include boys and girls from 11–14 working together in every class, and the Senior Girls' School which caters for girls only, aged 11–14 years.

1. MIXED SCHOOLS

In the Mixed Schools, Hygiene and Biology can be continued during the first two years, boys and girls together; then the boys can branch off into Community Hygiene, and the girls into Infant and Child Care. In such a school the boys can co-operate by making various pieces of apparatus for the girls' use, in the practical workroom. This brings the right spirit into the work, because the home belongs to the man and the woman, and the boy is learning various ways of helping his wife in the future. The production of an article which is the joint work of boys and girls is a valuable piece of home training in co-operation.

2. SENIOR GIRLS' SCHOOLS

In the Senior School for girls only, this co-operation is not so easily effected. Nevertheless it is possible to work with the corresponding boys' school, and this fact should be borne in mind. There will still be the two years' Hygiene and Biology training, followed by the Infant and Child Care Course.

It is necessary that the subject should be taken in the last year at school. This allows time for the right foundations to be laid, without which all teaching in Infant Care would be useless. The girl is capable of wider understanding and vision at this age, and, incidentally, is more likely to have charge of younger brothers and sisters. She obtains the knowledge just before she leaves school, when she may become a nursemaid, or a general servant in a house where the care of young children will be part of her duties. This immediate use of the knowledge she is obtaining should be pointed out to her, and in this way her interest will be aroused.

Space does not permit much mention of the foundation work, but, to illustrate the importance of correct training in this way, a consideration of the problems of feeding both baby and toddler will show how essential it is that the girl should understand food values and their uses in the body. How can she otherwise understand the great part the mother's diet plays in the production of sound milk for the baby?—the comparison between human and cow's milk becomes meaningless. She cannot understand how to choose suitable food for the toddler, and correct methods of preparing and cooking the food, if she has not already a knowledge of Dietetics and the principles of Cooking.

In the teaching of Infant and Child Care, the knowledge obtained in Hygiene, Biology, Science, Cookery, Laundrywork, Housewifery, and Needlework lessons, is applied directly to the care of the baby and toddler in the home.

Staff

No one should teach this subject unless she has the desire to do so. There are many difficulties which will have to be surmounted, and enthusiasm and patience are needed. It would be better to exclude it from the curriculum than to leave it in the hands of an unwilling or lukewarm teacher.

Training of some kind is most helpful, as previously stated, and up-to-date knowledge must be obtained. However large or however small the school, one teacher should be in charge of this subject. She will need to co-operate with her colleagues in both the Junior and Senior Schools; in the former case to see that the early foundation work is correct; and in the latter to ensure that, during the first two years in the Senior School, the girl is receiving the preparation for the work in the third year. In the third year, all her practical activities in school could centre around this project; therefore all the teachers concerned with Needlework, Domestic Subjects, and Handwork will be drawn into the scheme and should be consulted by the one in charge of the work as a whole. Very careful planning and grading will be necessary to make the work of educational value, and to ensure that it dovetails in correctly.

There has been much discussion as to whether the correct place for the work is in the classroom or in the Domestic Subjects room. It is impossible to have it completely in either. Both must take their share. In practically every new Senior School, where there are girls among the pupils, the Domestic Subjects room or rooms will be part of the building, and this means that the Domestic Subjects teacher will be in close co-operation with the school, which is as it should be. The only point for consideration is whether the Domestic Subjects teacher or one of the general subjects teachers should be in charge of the scheme. In many cases the Domestic Subjects teacher will have received special training, and, as her work deals directly with the home, she should be in charge if she is capable. If, however, another member of the Staff is more suitable, she should be responsible for the work. Very close co-operation with the Domestic Subjects teacher is needed, as much of the practical work will be taken in her Department.

It is needless to add that all teachers who embark upon this work should be kindly disposed to babies and toddlers, and understand their moods and peccadilloes. Without this disposition, they would not wish to teach the subject.

The Scope of the Work

There is such endless scope that it is very difficult to find space to include all that could be written about it. To give a Syllabus is impossible, owing to the many and various types of schools, children, and staff. This can be understood readily from the preceding remarks. All schemes should include certain fundamentals, however, and therefore explanations of these will be helpful and useful.

Most schemes plan work dealing with the infant first, followed by that dealing with the toddler, but there is no reason why this order should be followed. It tends to give a very incomplete conception, and does not link correctly with the previous knowledge obtained in the Hygiene and Domestic Subjects lessons. There is too big a gap between the infant and the schoolchild, and, unless the connection between the infant, the toddler, and the older child is clearly shown, the work on the baby becomes an isolated factor, which is a wrong conception for the girl to form. It is very much better if she can complete each section of the work, linking it finally with her knowledge of the needs of the schoolchild, adolescent, and adult. In this way the cycle becomes complete. Many teachers feel that it would be wiser for the scheme to begin with toddlers and their needs, comparing with the schoolchild, and finally working back to the infant. This is far more logical than dealing with the infant completely and then, if time allows, tackling the toddler. It is most essential that all schemes should include the toddler, because the young girl is much more likely to have charge of a toddler than an infant, and will have much to do with her little brothers and sisters and neighbours' children. Therefore the knowledge obtained in school dealing with the management of these little people can be put into immediate use, and is invaluable. But the care and management of the toddler is so closely and carefully built up on that of the infant that it is almost impossible to separate the two, and therefore the wisest and most sensible schemes deal with both concurrently.

The scheme, to be of any value, must be the outcome of original and independent thought; but there are stepping-stones that all schemes must include, such as Clothing, Sleep, Food, Bathing, Exercise, Habit Training, and Management; and, in dealing with each of these, the needs of the baby, then the toddler, and finally the child commencing school, should be clearly and carefully taught. No section should be considered complete unless this is done.

Lack of time is the cry of every teacher with all subjects, and it is bound to be while the child must leave school at 14 years of age. But it is more especially felt by those teaching Infant and Child Care, because this subject seldom finds a place to itself on the time-table, the time allotted being, in most cases, taken from that allowed for Domestic Subjects or Hygiene. In the few cases where special time is allowed, it is usually far too short to cover any ground satisfactorily. It is amazing that a subject of such vital national importance and interest has been so neglected, and it is to be hoped that in future it will find a recognized place in every Senior School where girls are amongst the pupils.

No scheme can be planned until it is known exactly how much time can be allowed for the subject. Infant and Child Care should be taken during the last year at school; the girl is at the greatest age possible, then, either 13–14, or if the school age is raised, 14–15. The older she is, the more capable is she of understanding and appreciating the work, and, if taken immediately before leaving school, the knowledge will be fresh in her mind when she needs to put it into practice. She will come to the lessons with the necessary foundation knowledge, and will have acquired in Needlework, Handwork, and Domestic Subjects the skill needed to be able to tackle, and handle satisfactorily, the more difficult and complicated problems presented by the scheme. It should not be regarded by the Staff or girls as a new subject, but rather as a natural climax of all the previous work.

The girl will then have one whole year of three terms to give to this work of collecting her previous knowledge and applying it directly to the Home and the care and management of children.

The time allotted previously to Hygiene will be for this form of applied Hygiene, and may vary from 20 minutes to one hour per week, according to the importance the Head Teacher attaches to the subject. Obviously the longer the period the better; and in cases where only a short time is permitted, the teacher in charge must try to infuse some of her enthusiasm into her Head, and have the time extended if possible. If, for various reasons, this is impossible, then the scheme must be cut down very carefully to fit into the time allotted. This weekly lesson forms the backbone of the scheme, and it is there that the drawing together of all the threads, and the tying together to make a whole, will be done. Without this definite linking-up, other contributory lessons will be isolated, and consequently will lose much of their value. This point cannot be emphasized too strongly, and it is obvious that all teachers of contributory subjects must work in very close alliance.

Co-ordination with Needlework

The Needlework lessons should deal with the clothing, bedding, and any household articles designed for the use and comfort of the baby and toddler. The Board of Education recommends that the older girl should concentrate on outfits rather than individual garments, so that she can obtain a conception of clothing as a whole. In making outfits for the infant, toddler girl and boy, and schoolchild, she has infinite scope for putting this suggestion into practice. The garments are small and attractive, and provide an opportunity for her to use the skill she has acquired. If patterns and materials are wisely chosen, the clothes will be readily and easily sold—an important consideration, as every teacher of Needlework knows. The teacher can use her own discretion as to whether she allows one girl to complete an outfit, or whether she groups the girls, and allows each group to collaborate in one outfit. Both arrangements have their advantages, and the choice depends upon local conditions, size of class, etc. New materials should not always be used. In most homes, garments will be cut down and altered to fit younger members of the family, and therefore in school this practice should also be adopted wherever possible. The girls should be encouraged to bring old garments to school, and to learn there how to unpick and remodel them into suitable garments for younger brothers and sisters. This is teaching thrift in a very practical manner, and it should be remembered that mothers who buy garments at Jumble Sales, to recut and remodel, are usually buying much better material than they could afford to purchase if new. The teacher should insist that all old garments should be brought to school clean, and when unpicked they should, if necessary, be washed again, either at home or in the Domestic Subjects Centre. Often material can be dyed, and so rejuvenated, in a laundrywork lesson.

Domestic Science

The Domestic Subjects Department will co-operate during the last year with this work, and here much of the practical work can be done. It is easier for the practice in bathing the baby to be accomplished in this department. Part of the time allotted for cooking can be spent in preparing food suitable for the weaning period and the toddler. The laundry lessons should include the laundering of baby clothes, and the girls should learn how harmful soda, washing powders, and starch are to the tender skin of babies and young children. The ironing of small garments teaches, more clearly than anything else, the necessity of simple patterns to save labour, and the choice of good, washing fabrics for clothes that are so often in the wash tub.

In planning and working the meals the girl will learn how to choose wisely for the family so that the toddler can partake of some of the food prepared, because it is suitable for the digestion of a young child. A busy mother, with limited cooking accommodation and utensils, cannot prepare special dishes for the toddler, and therefore much of the food she does choose and cook should be suitable for all. It is important, also, that the father's special needs should be considered, and the girls should understand that such foods as cheese and pickles are unsuitable for the toddler. Knowledge of food values and wise marketing knowledge obtained by the girl will be needed in planning the family meals. During this last year she should have ample scope for planning the full week's meals; this will show her how to cater within the weekly income, and to spend the money available for food evenly over the seven days. The week's meals can be cooked in one lesson, by grouping the girls into seven groups, and making each group responsible for a day. These meals can then be set out neatly, and the whole class can see at a glance the full week's food supply, and can discuss of which the toddler can partake. This is an invaluable piece of work, and demonstrates clearly the need for careful thought and planning. The girls should be shown how to utilize all cold food left over from the previous day, and also the cooking should be planned to save fuel and time. The latter point is most important where there are young children, because the more time the mother can spare for training the toddler, and taking the young children out to parks and recreation grounds the better it will be for their health and the peace and happiness of the home.

Another useful way of teaching the planning of weekly menus is by using food models. These can be made very easily by cutting out coloured advertisements of foods, mounting them on cardboard, and fixing them into wooden stands with slots cut in one side to hold the model. The girls can make these either in the Domestic Subjects lesson or the Handwork time. In some cases the models could be drawn and painted in the Art lesson. They should be sorted out into various groups, such as Meat, Fish, Puddings, Fruits, Vegetables, Drinks, etc., and put into labelled boxes, and then the girl should be told to work out her menus, building them up as she goes. It is very helpful if the food value is neatly printed on the back of each model. For this purpose, percentages and quantitative values should be avoided; it is sufficient to put the names of the food-stuffs contained, such as "Protein, Fat, Sugar, Starch."

Co-ordination with Art and Handicraft

In the Art classes, the girls can work out designs for embroidering the little garments, cushion covers, cot and pram covers, feeders, etc. They can also draw and paint animals for pictures, bricks, etc., and posters can be designed illustrating various points and details for teaching the care and management of babies and young children.

In some Senior Schools, Handwork will have a separate time allotted to it on the time-table; if this is so, the making of soft toys, washable linen picture books with either embroidered or appliquéd pictures, felt slippers from old hats, hot-water bottle covers, crawling rugs, screens, etc., and the seating and reseating of small stools, are all pieces of work directly connected with the home and the baby and toddler, and are far more practical than many forms of Handwork often undertaken. These articles can be used in the various lessons on Infant and Child Care, and can be sold to the girls and parents. It is a wise plan to have an exhibition showing the collected work from all departments which is needed for a complete scheme on Infant and Child Care. This will serve many purposes. It will give the pupils an incentive to do their very best work, it will show how each little piece of work fits into the scheme as a whole, and it will act as a very definite piece of propaganda work to the parents when they come to view it.

If no time is allotted to Handwork, then the necessary articles can be made either in the Domestic Subjects lessons, the Art or Needlework lessons, or in the time allowed especially for Infant and Child Care.

APPARATUS REQUIRED

Certain apparatus for the actual lessons and practical work will be required, and must be made by the pupils in school during one or other of the above lessons. Co-operation with the boys is most helpful for this, and the most essential permanent apparatus is as follows—

Cot

The most satisfactory type is that of the hammock variety which is slung on to a folding framework. This can be made for a very small sum of money, can be kept clean very easily, and is light enough to move about comfortably.

Broomsticks form a very satisfactory medium for the framework, and should be put together in a similar way to the one employed for a folding camp stool. Six sticks, each 1 yd. long, are required. The bed, when open, should be oblong in shape, and should measure at the top 1 yd. × ½ yd., the sides being 1 yd. and the ends ½ yd. The broomsticks are used for the sides, while strong tape or binding is sufficient at the two ends. A piece of broomstick measuring ½ yd. is necessary to keep the legs steady, and should be fixed at each end at the bottom, about 3 in. from the ground. The bed itself should be made of very strong unbleached calico or sheeting, and should be put on in such a way that it can be removed easily for washing. Curtains and trimmings are unnecessary, and act as dust traps. Curtains also keep the air away from the baby.

A banana crate or cheese case forms a very satisfactory cot also, and if possible this variety should be made as well. The crate or case can be purchased for 8d. or 1s. from the grocer, and needs well scrubbing, rubbing down with sandpaper, and staining or painting. A lining of washable cotton material should be fitted in, in such a way that it can be detached easily for laundering. The most satisfactory way is to tack a piece of wide tape round the inside of the crate at the top, having previously sewn on one-half of a patent fastener at intervals of a few inches all round. The lining should have the other half of the fastener at corresponding intervals, and this enables it to be easily removed. Frills and outside trimmings should be avoided; the stained bars of wood form all the decoration needed. If preferred, the crate could be enamelled and decorated with painted animals or flowers.

The bedding consists of two mattresses made of unbleached calico, filled with chaff. The under-mattress should be filled firmly, the top one half-filled only. A spare cover should be made, so that, if the top mattress becomes soiled, the chaff can be removed, any lumps taken out, and then repacked in the clean cover. A piece of mackintosh should cover the mattress, and over this should be placed a piece of quilted butter muslin at least eight layers thick. This is much better than a blanket, because it is easier to wash, and can be boiled. In the school, one only is needed, but with a baby two would be required for changing. The blankets should be arranged in the shape of a T. This allows the baby to be covered up with the warmth evenly distributed, and prevents untucking. The cheapest way to obtain good woollen blankets is to buy blanket-ends from any good manufacturer. These are ends from blankets which have some defect or flaw in them. The flaw is cut out, leaving pieces of varying width and size which are cheap and very good. In winter an eiderdown can be used as well, and this can be made very economically, in the rural areas, by using wool collected from the hedgerows. This must be well washed and teazled out with the fingers. It is light, soft, and very warm, being pure wool. It can be used also for stuffing the soft toys, forming an economical and washable stuffing. The pillow should be half-filled with chaff, and covered with a calico case. A pad of quilted butter muslin, six thicknesses, the length and width of the pillow, should be inserted between pillow and top case to prevent pillow becoming soiled in case of sickness.

A stone ginger-beer bottle with a cover makes an excellent hot-water bottle, and the correct place for it is at the foot of the cot between the two mattresses. This ensures that the warmth will be gentle and even, and, in the event of the bottle bursting, prevents the baby's becoming damp or scalded.

The well-filled under-mattress prevents sagging, and consequent damage to the baby's spine. The loosely filled top mattress is for comfort.

In the country, very cheap blankets can be made by using well-washed sheeps' wool placed in a thin layer between cheese cloth, and quilted. A good-sized cot blanket can be made for from 1s. 6d. to 2s. if the wool used is collected from the hedges.

Substitutes for cots should be taught; such as wide drawers, clothes baskets, half a Japanese travelling basket, etc.

Screen

This is very useful for preventing draughts in the kitchen when baby is being bathed, and can be used also to protect cot or pram.

If a screen is impossible to obtain, one can be improvised by hanging a blanket over the clothes-horse; or a cretonne cover can be made and attached to the clothes-horse by elastic loops at the top and bottom. For school use it is wise to show this and a small model will answer the purpose. For actual use, the boys can make the framework, and the girls can cover the screen. Hessian panels worked in gaily-coloured wools look very attractive, and are cheap and satisfactory. They can be put on in such a way that they are easily removed for washing. The inner side of the screen should be fitted with pockets to hold the baby's clothes, etc., and a strong tape or cord should be fixed across one panel to take towels.

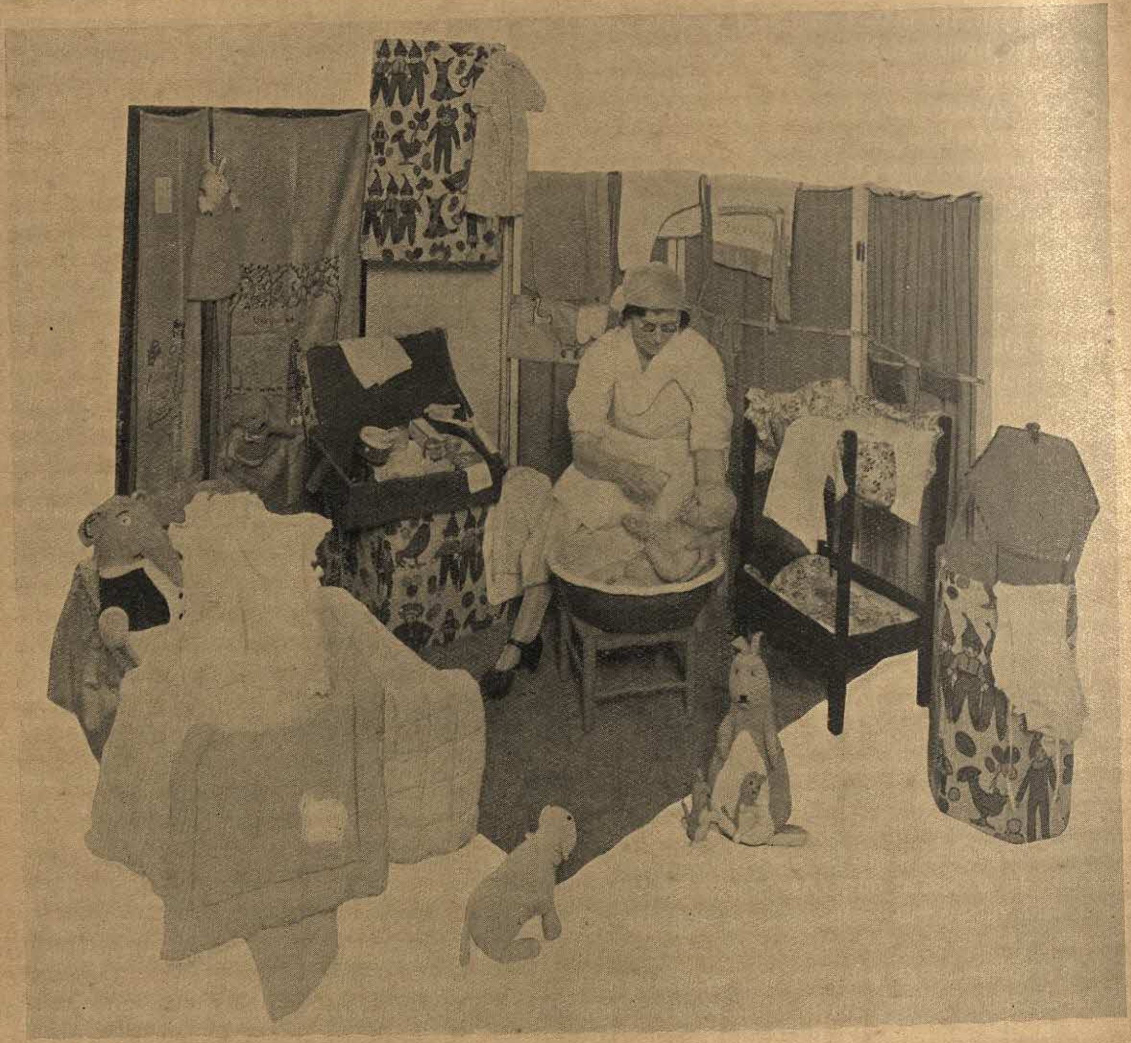


FIG. 2

A Demonstration on Bathing the Baby

Bathing Apparatus

It is most important that the girl should realize that the baby's and the toddler's bathing requisites should be kept for his or her individual use. She will readily understand this from her previous lessons in Hygiene. The main difficulty in a small over-crowded home is storage, and ways of overcoming this problem must be shown. A sixpenny tray, enamelled white, provides a good place to keep the soap and dish, the two lotion pots, scissors, cotton wool, washing cloths, etc. This can be covered over with a white cloth with weighted corners, and kept on the top of a cupboard or on a shelf. A Tate sugar box can be converted into a stool with a padded or sprung lid and a tray fitted inside. The enamelled tray with all the small requisites and towels can be kept in the tray of the box, and the baby's clothes in the body of the box underneath. The box when closed forms a seat, and is a piece of furniture. Incidentally, all the baby's things are together and are easily found—an important point in a small home. The best soap to use is Castile or White Windsor, and no powder is needed.

In the school a special bath can be kept for bathing practice, but in many homes this will be impossible, and the zinc bath used for other purposes will have to be used for bathing the baby. It is essential that the girl should realize that the bath should be well scrubbed and rinsed to free it from dirt and any traces of soda before it is used for the baby.

The Doll

This presents a very great difficulty at the moment, because there is no doll on the market that is absolutely suitable. The ideal doll should be the correct size and weight, with movable head, arms, and legs, and made of a material that will allow it to be bathed. A celluloid doll is too light and rigid to be ideal, although it has the advantages of being cheap and washable. The Kathe Kruse doll, obtainable through the Maternity and Child Welfare Association, 117 Piccadilly, London, is excellent for dressing and handling, but is expensive, and cannot be bathed. The Glaxo firm makes a rubber doll which baths well, but is not well proportioned, is difficult to dress, and is expensive. The Laugham Rubber Co., Ltd., make a rubber baby doll with a movable head, price £3. The address is 91 Fore Street, London, E.C.2. A comparatively cheap celluloid doll can be obtained from Bunneys, Ltd., Church Street, Liverpool, and can be used for dressing and bathing.

Clothing for the Infant

This should be made in the Needlework lessons for use in school, and at least three sets will be required. A set of woollies should be made also, so that the girl can decide between the use of long clothes or woollies. The respective merits of each type should be discussed.

Long Clothes

The most modern long clothes outfit consists of the following garments—

Long-sleeved vest fastening on the shoulder; napkin made of butter-muslin; gown or nightgown made of a woollen material, such as nun's veiling, wincey, or Viyella; and a matinée coat of the same material. Bootees and gloves should be worn in winter. A shawl and bonnet can be used for outdoor wear, or a thick knitted coat instead of the shawl. The gloves should be made in the shape of little bags with no thumbs. The butter-muslin napkins should be 1 yd. square, double thickness. At night, and when the child is going out, an over-napkin of turkish towelling, 23 in. square, should be worn.

Mackintosh knickers are very dangerous if worn continually. They cause chills and rheumatism. Body belts are not needed, neither are back-flannels, if the gown and nightgown are made of woollen material. If, however, they are made of cotton, then a flannel back-flannel is necessary. The girls should be warned of the danger of fire with flannelette, and should be advised strongly against its use.

It is unnecessary to have different styles for day and night gowns; if the same pattern is used for each, then fewer are required, and, when the baby is short-coated, the gowns can be continued as nightgowns. The best pattern allows for growth by small tucks over the shoulders, and wide sleeve with a turned-back cuff. A sensible pattern can be used that will fit the child until it is 18 months or 2 years old. It should have a pocket for the handkerchief. A list of the minimum garments required should be given to the girls, and the following is a practical number—

- 3 knitted woollen vests of soft 2-ply wool.
- 2 dozen butter muslin napkins.
- 2 dozen turkish towelling napkins.
- 4 robes or nightgowns.
- 4 matinée jackets.
- 6 handkerchiefs made of two layers of butter muslin.
- 3 pairs of gloves.
- 3 pairs of bootees.
- 2 coats.
- 2 bonnets.
- 1 shawl.
- 6 turkish-towelling bibs.
- 2 washing cloths made of 3 layers of butter muslin.
- 2 face towels made of 3 layers of butter muslin.
- 2 bath towels.

Woollen Outfit to Replace Long Clothes

This consists of long-sleeved vest and napkins as for long clothes. Over this a short flannel petticoat in winter, or cotton or silk petticoat in summer, should be worn; then a knitted jumper, and a knitted bag with straps from the back to cross over to the front and fasten with buttons. Viyella wool wears and washes excellently, and can be used for these outer garments. The knitted bag, such as is used by the Middlesex Hospital, is very much better than pullovers. The latter quickly become too small and tight, and do not allow the legs enough freedom of movement, and because they fit closely, are liable to become soiled, and to shrink and felt. Bootees and gloves should be worn in winter. The petticoat is necessary to prevent the wind blowing right through the clothing, as it would do if only knitted garments were worn. The baby who wears long clothes can wear woollies when short-coated. If, however, a frock is preferred, it is not necessary to wear a petticoat. It is necessary in this case to put on woollen knickers over the napkins, and a small flannel bodice over the vest. The knickers should have a tab on each side to button on to the bodice. A loose elastic can dispose of fulness, but should not be tight enough to keep the knickers in position. The tabs are for that purpose. It is very harmful for a baby or young child to have any constriction round the middle of the body. Bootees, or socks and soft shoes, should be worn.

Useful Patterns

Directions for Knitted Bag (used in place of pullovers).

Length of bag when finished: 17 in.

Length of straps when finished: 9½ in.

Wool: 4-ply Viyella. Size of needles: No. 8.

Cast on 48 stitches. Knit three inches of ribbing: 2 purl, 2 plain. Then knit the row following the ribbing in plain knitting, increasing once in every fourth stitch. Continue in garter stitch, increasing once at each end of every other line for 11 times, making 22 lines in all.

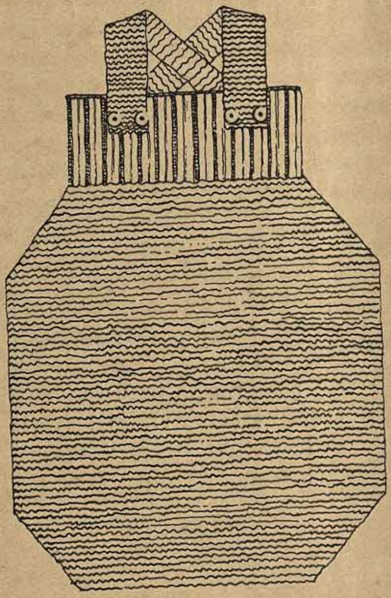


FIG. 3
The Knitted Bag

Knit 8 in. without any increasing.

Decrease at each end of every other line until there are 48 stitches left. Knit 2 lines.

Increase at each end of every other row until there are 82 stitches.

Knit 8 in. without increasing.

Decrease once at each end of every other row until there are 60 stitches. Knit one line, decreasing once in every fourth stitch, leaving 48 stitches.

Knit 3 in. of ribbing, and cast off loosely. Join up sides; sew on straps and buttons.

Straps. Two are required. They are stitched at centre back of bag, 1 in. apart. Place tape behind to prevent bag from tearing.

Cast on 40 stitches and knit 6 rows. Make two buttonholes at one end with four stitches between. Knit 4 rows and make two more buttonholes opposite the first two. Knit 6 rows. Cast off. Crochet round edge to strengthen. Sew two buttons on either side of front. The pairs of buttons should be 4 in. apart.

BABY'S VEST, FIRST SIZE (Open on shoulders).

Materials. 1 oz. Lady Betty 2-ply wool; 2 needles, No. 12.

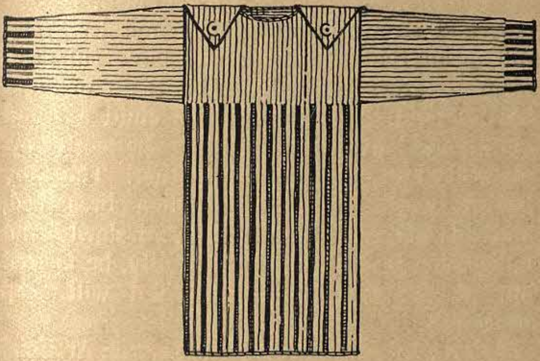


FIG. 4
Baby's Vest

Front. Cast on 60 stitches. Knit 2 plain, 2 purl for 8½ in. Continue in stocking stitch for 3¼ in. Cast off centre 20 stitches and knit sides 1½ in. Cast off.

Back. As front until centre 20 are cast off. Knit sides 1 in., then decrease at beginning and end of each row until 2 stitches are left. Cast off.

Sleeve. Cast on 60 stitches and knit in stocking stitch, decreasing every sixth line until there are 52 stitches. Continue without decreasing until work measures 5 in., knit 1 in. in ribbing 2 plain, 2 purl.

To Make Up. Sew sides together to top of ribbing. Wrap back over front for 1½ in. at shoulder and set in sleeves.

Work round neck and shoulders in double crochet, making a loop at each point. Sew on buttons.

DIRECTIONS FOR MAKING ROBE OR NIGHTGOWN.

Material: 1½ yd. of 30 in. material, cotton or woollen.

Measurements—

Length from Shoulder to Hem: 30 in.

Neck: 9½ in. when fastened.

Shoulder: 3 in. when finished. Four ¼ in. tucks in the shoulder allow for growth and can be let out as required.

Sleeve: Width at cuff, 8 in. total; width at shoulder, 10 in. total. Fold in half.

Length of underarm seam, 7½ in.

When sleeve is made, fold back 1½ in. to form a cuff. This can be let down as the child's arm grows. The sleeve can be either set in, or cut magyar. It will appear wide for the new baby, but this is an advantage as it is easy to put on. As this garment will fit the child until it is 18 months or 2 years of age, it is not any too wide for the older child.

When cutting out the neck, cut 1½ in. bigger than is needed when the neck is completely neatened; put in a box pleat taking in this extra width. This can then be let out as the child's neck grows, without unpicking the neck.

The opening can be at either the centre front or back, and should be one-third total length of garment.

The total width across robe from one end of sleeve to the other, before turning back to form cuff, is 27 in.

The total bust measurement should be not less than 28 in.

A pattern for this garment may be obtained from Miss V. B. Mann, 22 Calebrook Avenue, West Ealing, London.

Clothing for the Toddler

Complete outfits for the toddler, boy and girl, showing suitable clothing for summer and winter will be needed, and, for demonstration garments, are very useful. Simplicity of style, even distribution of warmth and weight, and material that will wash and wear well, are all points that must be considered.

In winter the girl should wear a long woollen vest or pair of combinations, flannel bodice, warm knickers with linings, and a frock made of wool or woollen material. The boy will wear similar underclothing, with trousers and jersey. In summer a light woollen vest and a thinner bodice, with cotton knickers and dress, or tunic, will replace the winter outfit.

Diagrams or Posters

Many suitable ones can be purchased, but the most valuable are those made either by the teacher, or by the girls in co-operation with her. Large clocks drawn on cardboard, showing 24 hours, are useful to illustrate a lesson on Feeding and the importance of regularity of meals. They serve also to show how to plan a day for the baby or the toddler, giving the right proportion of waking and sleeping hours. The young baby should spend most of the day and all the night in sleeping, waking only for food, bathing, and attention. The girl should understand what an important part sleep plays in growth, and that actual growth takes place only while the child is asleep. When she realizes that a normal baby doubles its weight in the first six months of life, and trebles it in the first year, she will understand how important it is that ample opportunity for sleep is permitted. The toddler needs twelve hours' sleep at night, and a sleep during the day of from 1½ to 2 hours. This daily sleep should be continued as long as possible. At 3 to 4 years of age, the child may not sleep, but rest lying down in bed is invaluable for a little body that is continually on the move during waking hours. The mid-day rest will help to prevent irritability and peevishness, as these are often the result of over-tiredness.

Food

The lessons on feeding the infant and toddler are most satisfactorily taken by the Domestic Subjects teacher. In dealing with the infant, the natural method of feeding is the only one which should be considered. The previous knowledge of Dietetics will form a sound foundation, and the girl will understand the foodstuffs and accessory food factors that are required by a healthy body. Starch must be omitted in any food given to a baby under 9 months of age, because the body is incapable of turning it into sugar and utilizing it before that age. Ptyalin, the ferment needed to change starch into sugar, begins to develop at 6 months, but it is not until the baby is 9 months old that it is present in sufficient quantities to change all the starch. Starch, as starch, is useless to the body, and is actually harmful, causing indigestion, stagnation of waste matter, and putrefaction in the intestine. Milk is the only satisfactory food for a young baby, and obviously its own mother's milk is the right food. The foodstuffs are in the correct proportion, the heat is just right, it is free from germs, and is clean. The suckling develops a wide mouth, a good jaw, and strong healthy facial muscles. This will mean that the teeth will have sufficient room to grow correctly. The teats of most bottles tend to develop in the child a round mouth and narrow jaws, making the teeth grow unevenly and on top of each other. The baby has to work for his food when breast-fed, and this makes him take it more slowly, and indigestion is unlikely. Incidentally, he is tired out at the end of a meal, and will sleep peacefully.

It is a waste of time to give lessons on Artificial Feeding. No girl of 14 years of age would be able to advise on such an important point: it is far wiser to leave it entirely alone, giving the class to understand that such feeding is abnormal, and must be done under expert direction only.

The lesson on Natural Feeding can be illustrated by such pictures as Salario's "Madonna of the Green Cushion," Rackham's "Springtide of Life," etc.

The importance of feeding regularly by the clock should be emphasized, and the intervals between the feeds should depend upon the baby's weight. A baby weighing from 7 lb. to 10 lb. should be fed at three-hourly intervals, over 10 lb. at four-hourly intervals, with no night feeds in either case. A baby weighing under 7 lb. needs expert advice. It is usual to give the first feed at 6 a.m. and the last at 9 or 10 p.m. The baby should take 15–20 min. over each feed. If the food is taken too quickly, indigestion will result; if too slowly, it is bad for the mother. Nothing should be given between meals except plain boiled water, and this can be given whenever the baby seems thirsty. A jugful should be prepared freshly each day, and kept covered. At 6 months orange juice can be given midway between the 10 a.m. and 2 p.m. feeds, and a hard crust to nibble before the feeds. At 8 months, bone broth should be given at the 2 p.m. feed in addition, and from this age onward the weaning process should commence. This must not be hurried in any way, and should extend over a period of 2 months at least. New foods should be introduced one at a time at the mid-day meal, and the baby should be accustomed to one food before a fresh one is tried. A large quantity of soft and pappy foods should be avoided, as the teeth and the muscles of the jaws require work to do. The lesson of correct mastication of solid food must be learnt from the beginning. If too soft foods are given, the baby learns to swallow them without chewing, and so a bad habit is formed. Cows' milk should gradually replace the mother's milk, and should form the staple diet during the weaning period; in this way the baby is not depending upon the solid foods for nourishment in the beginning. As he becomes more accustomed to solid food, its quantity can be increased, and the milk ration decreased in proportion.

The order in which feeds should be dropped and other meals substituted is as follows: first the night feed, then the early morning feed, and then the other feeds should gradually be altered in time so that they fit conveniently into the usual meal-times of the home, or are at such times as suit the mother best, becoming breakfast, dinner, and tea. Orange juice or peeled and cored apple may be given on waking. In many cases, as soon as the difficult weaning period is over, the toddler is expected to eat the usual meals prepared for the family. It should be emphasized that at least 1 pint of milk a day should be given to the toddler, and that rich heavy foods are bad, as well as heavily spiced and highly seasoned foods. The family meals should be such that the toddler can partake of them, and therefore this must be borne in mind when planning the day's menus. The value of skimmed and scalded milk should be taught in areas where they are obtainable.

Teething and Care of the Teeth

From previous Hygiene lessons, a knowledge will have been obtained of the constituents in food needed for the formation of healthy teeth; namely, Calcium and Vitamin D. The latter is needed to help the body to utilize the Calcium, and so form strong, sound teeth. Calcium without Vitamin D is useless. Sunshine acting on the skin will produce Vitamin D, which is found also in milk and animal fats such as butter and cream. In winter, a small teaspoonful of Cod Liver Oil daily, will provide the required amount of Vitamin D. Calcium is found in milk.

The teeth begin to form the sixth week after conception, and therefore it is essential that the prospective mother should have plenty of animal fats and milk in her diet so that she may obtain the materials needed to form the baby's teeth. If her diet is not correct, Nature will ensure that the baby will not suffer by taking the necessary materials from the mother's own body, and this will cause decay of her own teeth. When the baby is born, the mother's milk will supply the materials required to keep the teeth healthy and assist in their growth, and also to form the second teeth which will become the permanent ones. The first tooth appears usually between the sixth and seventh months, and the full twenty teeth should have made their appearance by the end of the second year. As soon as the baby has two teeth, a small soft tooth brush should be bought, and the teeth cleaned at bedtime, using warm water and bicarbonate of soda. It is a good plan to give the child a piece of raw apple after each meal as soon as he has sufficient teeth to chew it properly, as this acts as a natural cleaner. During teething the baby may be fractious owing to sore and swollen gums. No soothing syrups or teething powders should be given, as these usually contain drugs, which act as sedatives but do not cure the trouble. Very great care should be paid to the condition of the bowels, as constipation will add to the irritability. Indigestion must be avoided, and plenty of boiled water should be given to drink. Special care must be taken to avoid chill if there is inflammation.

The diet of the toddler must contain plenty of Calcium and Vitamin D, as it must be remembered that the permanent teeth are growing in the gums, and it is therefore essential that plenty of milk should be given. It is wise to encourage the toddler to clean his own teeth as soon as he is capable. This teaches independence, as well as inculcating a good habit.

Habit Formation and Character Training

Each baby is a separate individual, and as such will have a separate identity. No training should seek to cover or hide this, but rather to draw it out, and to make the child a useful member of society. Civilization demands certain things from its members, and the baby must be trained to fit into its right niche as early as possible, that is, from the moment he is born. Self-control is one of the most valuable lessons to be learnt, and all habits should have this as the basis.

The nurse and mother should train the baby to evacuate the bowels and bladder at regular intervals by systematically holding the baby out immediately on waking, and after each feed. He should sleep at night in a darkened room, and must go to bed at the same time every day, and be bathed at the same time every morning. Regularity should be the keynote of the baby's existence: he should live by the clock. This will develop a sense of order and punctuality, and will make him contented and sweet-tempered. Regular times for feeding with no food between meals will form a good, sound appetite and digestion.

Those who handle and deal with the baby and toddler should be quiet, gentle, and firm in their movements and speech. Sudden noises and erratic treatment make a nervous baby.

The toddler should be treated as an individual, and given a special place in the home. He should be taught and encouraged to dress himself, feed himself, and look after himself in simple ways. He should have a box, or a shelf in a cupboard, where he can keep his toys and small possessions, and should learn to keep them in a neat and orderly manner. He should be encouraged to play alone, as this will develop initiative and imagination. The poorer children are luckier in this respect than the richer ones, because the latter are usually so carefully guarded.

Great stress should be laid on this part of the work—the care of the toddler—in the lessons in school. The Senior girl will often have charge of toddlers, and she should know how to manage them wisely. If she can spend some time in a Nursery School, the toddler room of a Welfare Centre, and even the lowest class of the Infant School provided she can be under the guidance of a good teacher—she will be learning an invaluable practical lesson. There is a very great scope for this work, and far more might be done in this direction with great advantage to the Senior girls.

Signs of a Healthy Baby

It is essential that the girls should be able to recognize a healthy baby, and should know what to look for.

1. WEIGHT.

This should increase each week for the first year, usually 4 oz. per week. At 6 months the birth weight should be doubled, and at 1 year should be trebled. From 1–2 years the average gain should be about 8 lb., from 2–3 years about 5 lb., and from 3–4 years between 3 and 4 lb. Loss in weight, or no gain, is an indication that all is not well with the baby; hence the advantage of weighing weekly.

2. CONDITION

The eyes should be clear and bright; the skin clear and freshly coloured, and free from spots or rash; the flesh on the limbs should be firm and hard and mottled in colour. The grip should be strong and determined. The legs should kick firmly. The cry should be loud and strong; a whining or fretful cry is a bad sign. The girls should be taught to recognize the cry of hunger, which is loud and insistent, and the cry of pain, which is usually spasmodic, and accompanied by other signs of distress, such as drawing up the legs when the pain is in the abdomen, rubbing the head when in the ears or head. The bones should be firm and comparatively straight in the limbs. Swelling at the ends, pain on touching, and curvature are signs of rickets.

3. DEVELOPMENT

Lessons on the normal physical and mental development of the baby and toddler should be given. Thus small abnormalities will be quickly recognized and expert advice and treatment obtained. The weekly attendance at a Welfare Centre is an invaluable help to the mother, as the baby and toddler come regularly under the supervision of the Health Visitor and Doctor.

It will be seen that the syllabus should include lessons on clothing, correct laundering of baby garments, sleep and sleeping arrangements, food, teething, bathing, management and habit training, and the normal mental and physical development of the child.

It is most important that in each section the infant and the toddler should be considered; this has been mentioned previously, but it cannot be emphasized too strongly. Much of the faulty presentation of Infant Care Teaching has been in the exclusion of the toddler. For example, in the Food Section the order of the lessons should be Natural Feeding, Weaning, Food suitable for the Toddler. When the three parts have been dealt with, then the next section can be commenced.

Conclusion

There is much confusion in the minds of many teachers and parents as to what is meant by the term Infant and Child Care, or Mothercraft, teaching. Some prejudice has arisen because it is thought that it is a subject that deals with what are commonly termed "the facts of life." It should be clearly understood that the reproductive organs and their functions are not taught in these lessons. There is no need to consider the origin of babies in this work, and it would be, in any case, an unwise proceeding to do so as a class subject, unless very careful preparation has been made beforehand. The right time to give this knowledge is when the child first demands it, and that is usually at a very early age, and the right one to impart such knowledge is the mother. The Teacher is usurping the mother's privilege when she gives the information, and should do so only with the mother's knowledge and consent.

The beginning of the adolescent period is not the correct time for knowledge which may come as a shock; the body is growing very rapidly, the reproductive organs are developing, and all the child's energies are needed to cope with her body's demands. Her nervous control is not at its best, and anything in the nature of a mental shock should be avoided. Lessons on reproduction as a class subject are exceedingly dangerous at such an age. The teacher cannot know what previous knowledge each individual child has on this subject, and she cannot foresee how every child will react to the information. It is much wiser to leave such teaching alone when dealing with the elementary schoolchild, unless a carefully-graded scheme is planned with the consent of all the parents.

A lesson on the hygiene of the menstruation period should be given during the girl's last year at school, as much discomfort and future ill-health can be avoided if the girl understands this function correctly. She should be taught the importance of cleanliness at such times, and the necessity for daily washing all over. The dangers of chill and constipation should be explained, as these are often the cause of unnecessary pain. It is a wise plan to have at least one office, with a bolt on the door, reserved for the senior girls, and on the inside of the door a notice should be placed giving the name of the teacher to whom the girls can apply for sanitary towels, if necessary. Much unnecessary discomfort and unhappiness can be avoided if attention is paid to this detail. It is a wise plan for the teacher in charge of the Infant and Child Care scheme to undertake this duty. If she deals with her subject in a sympathetic way, the girls will confide their personal problems to her, and she will be able to give much advice on health matters. The mothers will appreciate this considerate care of their girls.

The Infant and Child Care Scheme should be a thread running through most of the school subjects, linking them together, and bringing the school and the home into close connection. It will develop the natural love of young children that every healthy, normal girl possesses, it will make her wise and careful in dealing with any babies who come into her charge, and above all it will lay the foundation for normal and happy motherhood.

GOOD REFERENCE BOOKS

The Mothercraft Manual, by Mabel Liddiard.

Feeding and Care of Baby, by Trilby King. (Macmillan & Co., Ltd.), 2s.

Health and Education in the Nursery, by Bennett and Isaacs. (Routledge), 6s.

Health in the Nursery, by Bennett. (Routledge), 6d.

The Nursery Years, by Susan Isaacs. (Routledge), 6d.

DIETETICS

THE world to-day is full of so many marvellous things that many people forget the most wonderful thing of all—the human body. Each living body is a miracle of co-ordination, and each part of it works so smoothly with the rest that it is only when something is out of order that attention is drawn to its mechanism. Man is so accustomed to his body working correctly that little warning signs that all is not well are often neglected, and when at last notice is compelled it is often difficult, and even impossible to repair the wrong.

Keeping the Body Healthy

Care is essential for all machines; upon this will depend their smooth running, and a fuel must be chosen to suit their particular needs. The body is often likened to a machine, and like other machines needs careful thought in choosing the right fuel. Food and air act in this capacity for the human body. Unlike other machines, the body can repair itself, renew worn-out parts, and keep itself in sound working order if the right materials are provided.

Prevention of ill-health is the duty of every individual; the body can fight and overcome disease germs, in the majority of cases, if it is kept in a healthy condition, but it cannot be healthy if it is underfed, overfed, or wrongly fed.

Co-ordination of the Cells

The fabric of the body is composed of millions of tiny cells, each having a special piece of work to perform. This is division of labour in its widest sense.

The amoeba, which is the lowest form of life we know, consists of one cell only, and all the processes of life—breathing, feeding, movement, growth, excretion, and reproduction—must occur within the walls of that one cell. It resembles someone living in one room, and all the activities required for living must occur within its four walls.

The human body resembles a community of people living together in a house with many rooms. Each room has its special use, and certain people are delegated to work there at allotted tasks.

In the human body certain cells attend to the need for air, others extraction from it of oxygen, others attend to the need for food, its digestion and assimilation, others to the removal of waste material, others to repair and growth, and the formation of the framework to hold the tissues, and others again to directing and governing this wonderful collection of busy cells.

Their functions have decided their shapes, sizes, and composition. It is common knowledge that everything in the world is composed of materials termed elements, and certain of these form the cells of the body—chiefly Oxygen, Hydrogen, Nitrogen, Carbon, Sulphur, Phosphorus, Iron, and Calcium. All cells have a common foundation material called Protoplasm, and in addition have additional elements, or larger proportions of certain elements, because of their special function. For example, the cells of the bones and teeth need a large supply of calcium, those of the blood require iron, the brain phosphorus, the flesh nitrogen, the fat Carbon and Hydrogen, etc.

These elements are found in air and food, and therefore the body requires these two things to provide for growth and repair of waste tissues. Energy and heat are essential for life, and air and food provide the materials necessary to produce both.

A well-balanced diet is one that provides all the necessary elements in the food, in the right proportions. If the food is correctly served and cooked, the daily needs of the body are met, and provision is made for the storage of certain materials for the production of heat and energy, and for emergencies.

Health and Food

A well-built house depends upon three things: namely, good foundations, the best materials in the form of bricks, wood, glass, slates, etc., and skilled workmanship.

A healthy body can be likened to it—the good foundation is a clean and wholesome heritage, the best materials are found in wisely chosen foods, and the cells of the body will provide the skilled workmanship. It cannot be emphasized too often that the cells of the body cannot work properly unless they are kept in a healthy condition, and are provided with the right material. Both these points are effected by the elements in the food, and therefore the dietetic value of the food is a vital point for consideration.

Food is composed of foodstuffs and accessory food factors.

Foodstuffs Found in Foods

PROTEIN, FAT, STARCH, AND SUGAR

These are essential for building the fabric of the body, as they contain the necessary elements to accomplish this work. The Digestive Apparatus is able to extract the required elements, by a process of breaking down the foodstuffs, and then the cells can utilize these materials for repair, growth, reproduction, or the production of heat and energy.

PROTEIN

This foodstuff contains Carbon, Hydrogen, Oxygen, and Nitrogen; it is the body's only source of Nitrogen, and for this reason foods containing it are often referred to as Nitrogenous Foods. It is essential for the formation of Protoplasm, the foundation material of all the cells of the body, and therefore is vital to life. Every diet must contain a proportion of protein daily, as unlike the other foodstuffs it cannot be stored in the body. Any excess over the body's daily needs is excreted as waste. For this reason a diet too heavy in protein is harmful, as it throws a great strain on the kidneys, which are the organs of excretion used in this case.

Protein is found in the flesh of animals such as beef, mutton, lamb, pork, veal, poultry, birds of all kinds, in fish, eggs, cheese, milk, nuts, and pulse vegetables such as peas, beans, and lentils. These last are able to extract Nitrogen from the air in the soil, by means of certain nodules on their roots, which contain bacteria.

Protein is found also in other grains and vegetables, but is not in sufficient quantities to allow such goods to be taken as a sole means of providing the body with nitrogenous material.

Nuts are very rich in protein.

Protein is graded into two classes. The first class consists of all the sources from the animal world. The body can break these foods down and obtain the required material more easily than from the protein obtained from the vegetable world. The more difficult it is for the body to extract the required material from a foodstuff, the more difficult is the food containing it to digest.

The quality of the protein obtained from animal food is higher than that from vegetables, and therefore more of the latter is required. If food of vegetable origin is relied upon for the source of protein, it becomes a very bulky way of obtaining Nitrogen.

A diet in which all the protein is obtained from the animal world is expensive, and would in many homes be prohibitive. The best proportion is $\frac{1}{3}$ animal protein and $\frac{2}{3}$ vegetable protein. This is suitable for the average individual, but young children, old people, and convalescents, whose digestive apparatus is not as strong and fit as it should be, will need more animal protein than vegetable, because it is so much easier to digest.

It should be remembered that protein is needed as the source of Nitrogen; it should not be required to provide heat and energy, although it is capable of doing this. The other foodstuffs will produce both more economically, and sufficient quantity of these should be taken to ensure that they are doing the work, otherwise protein will be used for this purpose, because heat and energy are the body's primary needs.

The normal adult and growing child will need $3\frac{1}{2}$ oz. or 100 grammes of protein daily.

There are many varieties of proteins in both classes, such as casein in milk and cheese, albumen in white of egg, legumen in peas, beans, and lentils, gluten in flour, myosin in meat, etc.

Most of them coagulate on the application of heat; casein in milk is an exception. Acid has a hardening effect on proteins, and should not be used as a general rule in cooking them.

Very strong acid foods are bad for the lining of the walls of the digestive apparatus, i.e. the stomach and intestines, as they tend to harden the protein and render the tissues less elastic. This elasticity is an important factor in digestion. Very strong stewed tea contains tannic acid in sufficient quantities to have a harmful effect on the walls of the stomach.

Fat

Fat contains Carbon, Hydrogen, and Oxygen. It is a very valuable foodstuff and has many uses in the body. It is the best producer of heat and energy of all the foodstuffs, and it makes fat cells needed for the storage of fat, padding, and the keeping of certain organs in their right place, for example, the kidneys.

It provides the oil needed for oiling the various parts of the body, particularly the large Intestine, where it assists the smooth passage of the waste material and so prevents constipation. It is found in all animal fats, such as that on meats of all kinds, dripping, suet, butter, lard, cream, cheese, milk, and in oily fish, as herring, salmon, eel.

Fish that have a white flesh when cooked have the fat in the liver only. It is not distributed throughout the body; the cod is a well-known example of this type, and from its liver is made the oil that has such valuable dietetic properties apart from its value as a fat. This type of fish is valuable for any whose digestion is not strong, as the absence of fat makes it very easy to digest. The fish with coloured flesh on cooking have the oil distributed throughout the body, and are therefore more nourishing to the normal individual. Herrings contain both first-class protein and fat, and are often referred to as "the poor man's dinner." From a dietetic point of view they are a very economical proposition.

In addition to the animal fats, there are the vegetable oils. Nuts and olives are rich in these, and the public can obtain various preparations containing these fats, such as olive oil, margarine, nutta, and various kinds of vegetable butters.

If fat is examined under the microscope it is found to consist of globules, and fat that has its origin in the animal world is in much finer globules than in that from vegetable sources. In the process of digestion, it is necessary for the body to break up the fat globules and form a very fine emulsion. The smaller these globules are at the beginning, obviously the less work will the body need to do, and therefore it follows that animal fat is more easy of digestion than vegetable. This is not a very important factor when dealing with the normal healthy child and adult, but becomes vital when the digestion is impaired, in sickness and convalescence, and in feeding the aged and the very young. The globules of fat are much finer in human milk than those in cow's milk, and therefore on the fat content alone the former is easier for an infant to digest.

Most animal fats, with the exception of lard, contain Vitamins A and D naturally, and therefore are useful in promoting growth, preventing rickets, and keeping the nerves in healthy condition. They help also to raise the body's power of resisting disease.

Some vegetable fats, including many brands of margarine, have those vitamins added artificially, and have the same effect. Where margarine is used instead of butter, for economic reasons, it is important to buy a brand which has added Vitamins.

Another interesting point to note is that fats with a low melting point are most easily digested by the body.

The body needs 3½ oz. or 100 grammes of fat daily.

Sugars and Starches

These foodstuffs contain Carbon, Hydrogen, and Oxygen, but in proportions different from those in fat.

All foodstuffs must be soluble or the body cannot utilize them. Starch is insoluble in the digestive juices, and therefore is useless to the body as starch, as it cannot be absorbed. It must be converted into sugar, and this is accomplished by certain enzyones, or ferments, found in the digestive juices.

Starch is present in grains, seeds, and certain vegetables. All starchy foods such as custard, blancmange powders, cornflour, rice, potatoes, etc., should be well boiled, as this process renders the starch more easily converted into sugar.

Sugar is a foodstuff easily obtained; it is found in fruits, milk, honey, and many vegetables, e.g. beetroot and carrot, in addition to being on the market in its natural form.

8½ oz. sugar or 250 grammes are required daily.

THE USES OF SUGARS

Sugars have two distinct functions. They are good producers of heat and energy, and, although more bulky for this purpose than fat, they are invaluable because they are found in the cheaper and more easily obtained foods. The eating of a lump of sugar or a piece of barley sugar is a very quick way of producing energy. This fact may be an unconscious reason for a child's natural love of sweets.

Sugars are necessary also to help to assist in the combustion of the fat in the body. It is most important that the correct balance between the consumption of fat, sugar, and starch be maintained, otherwise headaches, biliousness, and indigestion result. Persistent sick headaches can often be cured by an increase in the daily sugar ration.

This important function of sugars and starches —the assistance in the fat metabolism—may be likened to the use of paper and wood in the lighting of a fire. They assist the more valuable heat producer—coal—to do its work.

It is unwise to take glucose indiscriminately. The prevalent idea that it is a valuable addition to the diet may lead to digestive disturbances, unless it is taken under the doctor's directions. Mothers should be careful to avoid falling into error on this point with children.

Starch should never be given to a baby under 8 months of age, as the saliva does not contain the ferment, Ptyalin, which is necessary to convert the starch into sugar. The starch is not digested therefore, and causes trouble in the digestive apparatus on its passage through the body. Large quantities of starch should be avoided in any diet, as it tends to be stored in the body in a form of fat that is flabby and useless, and lowers the child's fighting powers and resistance to disease, making the child liable to colds and chest troubles.

Excess sugar is stored in the liver and can be poured into the blood stream for emergencies.

Accessory Food Factors

These are Water, Roughage, Inorganic or Mineral Salts, and Vitamins. They are distinguished from foodstuffs in that they are not altered by the body, or broken down in any way, before they are used. The body needs and uses them in their original state.

WATER

Water enters very largely into the composition of the body, 65 per cent of the total body weight being due to water. It forms the chief constituent of the blood and the digestive juices, and it acts as a solvent for soluble waste materials. These impurities are removed as urine by the kidneys and as perspiration by the skin. Water vapour is excreted by the process of breathing. Consequently the body needs an ample daily supply: a minimum of three pints is required per day by the normal adult. It is found in varying quantities in all foods, and is the chief constituent of most fluids.

INORGANIC OR MINERAL SALTS

These form 5 per cent of the body weight, and are found chiefly in the teeth, nails, bones and hair, but small quantities are present in the other tissues, and are needed for various purposes. For example, Calcium is essential for the formation of firm hard bones and teeth, and it plays a large part in their composition, but it is essential also for the activity of every cell in the body, and without its presence in blood no clot can be formed.

The chief Mineral Salts are—

Calcium, Iron, Iodine, Chlorides, Potassium, Phosphorus, and Sulphur.

If a diet containing a liberal supply of milk, fruit, green vegetables, cheese, eggs, and fish is taken, these salts will be found in sufficient quantities for the normal daily needs.

Iodized salt and cod-liver oil will provide iodine if this material is lacking in the foods, or if the body appears to need an additional quantity. Those who live near the sea do not suffer from its lack as a rule. The lack of iodine will produce thyroid troubles, and this will lead to general ill-health, because the thyroid is one of the endrocrine glands, and intimately connected with all the others in this most important group. If one of the group is out of working order, the others become affected, and the Thyroid has often been referred to as the cornerstone of the Ductless glands.

Roughage

Stagnation in the large Intestine causes putrefaction of the waste material, and consequent absorption into the blood stream of poisonous gases and materials. This causes headache and general ill-health, because the cells are poisoned and drugged, and therefore cannot work effectively. Chronic constipation, which is the result of this stagnation, is probably the underlying cause of many serious illnesses.

The Intestines propel the food waste along to the rectum for excretion by means of peristaltic action, i.e. by means of muscles, which are situated longitudinally and around the tube of the Intestine. The contraction and expansion of these muscles propels the food along in small segments.

Fat oils the intestines and helps the food to move smoothly, and the eating of correct foods helps to keep the muscles fit and working well, and to provide bulky material upon which the muscles can work.

Roughage provides this bulk. It is found chiefly in the indigestible fibres of fruit and vegetables. Medicinal paraffin is made from this source, and cannot be digested or absorbed by the body; consequently it passes through the intestines, taking waste material with it.

Oatmeal, root, and green vegetables, fresh and dried fruits, e.g. prunes, dates, etc., nuts, foods made from wholemeal flour, etc., are all good sources of roughage.

Vitamins

These accessory food factors are essential for the well-being of the body. Lack of them causes certain disorders called "Deficiency Diseases." There is continual research work taking place on these substances, and therefore the knowledge of their uses, and characteristics, etc., is continually increasing and altering. It is possible that they may be regarded as a Catalytic agent, i.e. they assist in a chemical reaction in the body but remain unchanged themselves.

There are several known at the present time, and they have been given various names, but the most usual are those after the letters of the alphabet.

VITAMIN A

This Vitamin promotes growth, prevents certain diseases of the eye, and it raises the body's resistance to disease, chiefly those of the lung, and catarrhal conditions.

It is often associated with the yellow pigment in foods, and is found in butter, milk, cream, yolk of egg, young lambs, liver, green salads, and cod-liver oil. It has been proved that the amount of Vitamin A in cows' milk depends upon their food. Summer milk from cows fed out-of-doors on grass is rich in it, while winter milk from stall-fed cows is poor in Vitamin A. This points to the fact that expectant and nursing mothers should have a diet containing foods rich in Vitamin A, to ensure that their milk shall be rich in this vitamin.

Experimental work has proved that Carotin, the yellow colouring matter, is soluble in medicinal paraffin, and therefore it is possible, owing to the association between the presence of Carotin and Vitamin A, that the administration of medicinal paraffin which is not absorbed by the body may result in the removal of Vitamin A. This point, if it is true, is of vital interest to expectant and nursing mothers.

Vitamin A is not destroyed by heat, provided no air is present. Cooking in the presence of air such as frying, grilling, and boiling in open pans tends to destroy it.

VITAMIN B

Of this there are two groups, B1 and B2.

B1. This vitamin is destroyed by heating under pressure with an alkali, but ordinary household cooking does not harm it. It is found in lentils, peas, unpolished rice, yeast, yeast products such as marmite, all young embryos, such as eggs and cereal germs. Bemax (which is wheat germ), nuts, milk, liver, and cod-liver oil. This vitamin prevents beri-beri. This is a disease characterized by paralysis in the later stages. This paralysis is rarely seen in England, but this does not mean that beri-beri is not found here. Many cases of indigestion, abnormal appetite, pains in the joints resembling rheumatism, heart trouble, and general ill-health, and irritability are due to lack of Vitamin B, and are symptoms of a mild form of beri-beri.

B1 promotes healthy muscles, and this is particularly important in aiding the passage of the food through the Intestines, and preventing constipation. Lack of B1 produces flabby muscles, and causes the intestines to become paper-like in structure. This condition consequently affects the whole nutritional condition of the alimentary canal. Many cases of disorders of the nerves, and various neurotic conditions have their origin in lack of this vitamin.

Shortage of milk in a nursing mother can often be cured by the addition of Vitamin B to the diet.

A small amount of Bemax or Marmite daily will provide the necessary quantity of Vitamins B1 and B2 if they are lacking in the diet.

Vitamin B2. This is found usually wherever animal protein is found: if the diet contains enough of this type of protein, B2 will be present also in sufficient quantities. It prevents a disease called Pellagra, symptoms of which are skin trouble and digestive disturbance, with mental trouble in acute cases. Sunshine aggravates the disease, and possibly slight skin rashes produced on exposure to sun may be a symptom of a mild attack of pellagra.

When this vitamin was discovered to have powers separate from B1, it was originally termed PP, owing to its property of preventing pellagra. The more usual term now is B2.

It is found in Bemax and Marmite as well as being associated with animal protein.

Vitamin C

This vitamin is found in foods that have a pleasant appearance and taste, such as oranges, lemons, grape fruit, strawberries, gooseberries, rhubarb, lettuce, watercress, raw milk, and tomatoes.

Green vegetables such as spinach and cabbage are rich in Vitamin C when raw, but cooking will destroy it if it is prolonged and performed with the addition of an alkali such as soda. The oxidization which occurs when food containing Vitamin C is cooked is greater when the method employed is slow and prolonged. Boiling quickly will tend to expel the air, and consequently the oxygen, and if soda is omitted much of the Vitamin C content will be present when the food is cooked. Old vegetables and fruit that has been stored a long time tend to lose the Vitamin C content.

Many tinned and canned fruits and vegetables are prepared in such a way that the Vitamin C is not destroyed, and therefore such foods can help to provide it in the diet, although they should not be relied upon exclusively.

A deficiency of this vitamin will cause a disease called scurvy, and was the cause of many hundreds of deaths in the Navy and Army, and on exploratory sea and land voyages before it was realized that fresh lemon juice, orange juice, and fresh vegetables would prevent the scourge. This was discovered long before it was realized that it was the Vitamin C in these foods that gave immunity.

Scurvy is not a disease of the skin, as popularly supposed; it manifests itself primarily by pallor and lack of energy, followed by severe pain in the joints and swellings, often confused with rheumatism and neuritis; nose bleeding is a common symptom, and bleeding from the gums with loosening of the teeth. It is possible that many cases of mild rheumatism may, in reality, be due to lack of Vitamin C, and those sufferers who are cured by doses of lemon juice bear out this theory.

Certain cases of pyorrhoea may be due also to the same cause, and the diet should be considered very carefully in these cases before any more drastic measures are taken.

Bottle-fed babies are liable to suffer from mild scurvy, unless fresh orange juice is given daily. One teaspoonful diluted in an equal quantity of boiled water is sufficient to commence with; the dose can be gradually increased, and the amount of water diminished, as the baby becomes older. Many cases of fretfulness, sleeplessness, crying upon being touched, etc., in infants can be cured by this simple alteration in the diet. Grape juice has been suggested in place of orange juice, but it is useless, as too much of this juice would be required to give the required amount of Vitamin C.

Although milk contains Vitamin C, it is only in the raw state that it is present; pasteurizing and boiling destroy the Vitamin C, and, as this is usually done when the milk is to be used as food for an infant the necessity for orange juice is clearly demonstrated.

The effect of alkalis is important not only when cooking greens, when soda should be omitted, but also in preparing food for infants, when, to render it more easily digested sodium citrate or bicarbonate of soda are added. These two substances being alkaline destroy any Vitamin C.

VITAMIN D

Originally A was thought to possess all its own properties, plus those of D, but further research work proved that many of the properties attributed to A were due actually to an entirely different source, and this was termed Vitamin D. This vitamin has a vital effect on the formation of bone, and because it prevents and cures rickets, a serious and far too common deficiency disease of childhood, it is often termed the ante-rachitic vitamin.

For the formation of hard, strong, healthy bones and teeth it is essential that the body is served with a correct supply of the necessary materials, i.e. calcium or lime salts, and phosphates; but even when these substances are present in the right proportions, unless Vitamin D is present also, the body is unable to utilize them. It is comparable to the old proverb that "you can lead a horse to water, but you cannot make him drink." With a supply of Vitamin D, the cells of the body can use the calcium and phosphates for the formation of bone and teeth —without it, these substances are wasted, with consequent malformation of bone, bow legs, curved spine, pigeon chest, and uneven, decayed teeth.

Vitamin D is found in most of the foods where A is present, in oily fish, and in butter, especially that produced from the milk of grass-fed cows. This latter point is of interest in connection with the use here of New Zealand butter in the winter months, when most of our own cows are stall-fed.

Whole milk is a valuable source of both the mineral salts and vitamin D for growing children, to whom it is so essential, and children up to five years of age should have at least one pint of milk daily. Children over that age should have at least half a pint, more if the family income will allow it. Those adults who can digest milk and like it can take ½ pint daily with benefit.

For a long time there was confusion of thought with regard to the part played by Vitamin D and sunlight. Many very interesting and illuminating experiments have been made to clear up this point. It has been proved that the body obtains the vitamin in two ways, either as Vitamin D in the food, or as a substance called ergosterol. This latter substance is stored in the fat under the skin, and is activated, and converted into Vitamin D, by the action of the direct rays of the sun on the skin. The vitamin thus formed is carried by the blood round the body to the various cells requiring it.

The value of judicious sun-bathing and bare arms and legs for children in summer, summer milk, and butter produced from cows grazing in the sunshine, and the curative effects of artificial sunshine treatment, become obvious when this knowledge is understood.

The activation of ergosterol can be carried out by means of ultra-violet light, and the resulting Vitamin D can be added artificially to various substances, such as dried milks for infants, margarines, and malt.

VITAMIN E

This one is concerned with reproduction, and lack of it causes sterility. It is found in lettuce, milk, cod-liver oil, wheat, and certain vegetable oils. It is found largely where A and D are present, although it is not identical with them, and it is not destroyed by heat.

Utilization of Food

It is clear from the preceding information that in order to obtain a well-balanced diet it is necessary to include a variety of foods; in this way the body is certain to obtain the various foodstuffs and accessory food factors.

Careful planning of daily and weekly menus, wise marketing, proper cooking, and due consideration of individual likes and dislikes are essential if health is to be maintained. But the entire responsibility does not rest upon the housewife; each individual should understand the workings of the human body, and should be sufficiently versed in the laws of healthy living to give his, or her, own body a fair chance. However wisely chosen and prepared the food is, the body cannot utilize it to the best advantage if its apparatus for dealing with food is out of order. A detailed knowledge of this structure is not essential, but a general knowledge will help to prevent many of the common disorders which are prevalent.

The food in its passage through the body is dealt with in the mouth, stomach, small intestine, and large intestine. It is treated in various ways on its passage, which process is termed *digestion*, and it is absorbed after digestion into the blood stream and thus carried to the cells of the body, which process is termed *assimilation*. Digestion is both physical and chemical in nature.

Digestion in the Mouth

The teeth tear the solid food into little pieces. This renders it easier for the digestive juices to reach a bigger surface, and helps it to dissolve. The saliva mixes with the food particles, rendering them soft, and easy to swallow, and the tongue forms the material into small portions, or boluses, and throws it to the back of the mouth to be swallowed down the gullet, or oesophagus. Every child should be taught to chew food properly, otherwise too much strain is thrown on the muscles of the stomach, thus causing indigestion, and its attendant trouble in adult life. All food must be in solution for the body to digest it, and it is obvious that if it is swallowed in large lumps it will have to be pulverized elsewhere. If the teeth are dirty, or decayed, the poisonous matter will be chewed into the food, and swallowed, and is bound to have a harmful effect on the tissues of the body, because it will enter the blood stream with the digested foodstuffs, and be carried to every cell in the body.

The saliva has another function besides dissolving and moistening the food, and that is to convert any starch present into sugar, by means of the ferment *Ptyalin* it contains. The more the food particles and the saliva are mixed together, the more effectively can this chemical change take place. Hence another reason for well chewing food.

The teeth are exceedingly valuable, and it is essential that every mother should see that her child's teeth are strong and well formed, by paying careful attention to her own diet during pregnancy, from the very beginning, and by correct feeding of the child from birth. The prevalence of false teeth in early adult life is a disgrace to civilization.

Digestion in the Stomach

The muscles of the stomach act as a churn, and break up the food particles still further, until the mass resembles a thick soup. The digestion of starch is not continued for long here, as Ptyalin cannot work in an acid solution. There is a weak solution of Hydrochloric Acid in the stomach and as this mixes with the food it renders it acid. The digestive juice in the stomach called gastric juice acts upon the protein only, breaking it down into its constituent amino acids. The food remains in the stomach a varying length of time, according to the type of protein it contains and the amount of fat. Very fatty foods remain longer than those containing a small proportion of fat, because fat tends to delay the production of gastric juice. In order to leave the stomach all the contents must be acid: carbohydrates, i.e. sugars and starches, are quickly rendered acid and therefore do not stay long, but proteins and fats remain longer.

The churning action and the digestion of the protein content of the food occurs at the pyloric end of the stomach, i.e. the portion nearest to the small intestine. The cardiac end of the stomach, that nearest to the oesophagus, is not acid and allows the digestion of starch to continue for a short period. This explains the reason for the usual custom of eating meat before sweets.

Tight clothing, such as corsets, elastic bands, etc., around the waist restrict the stomach and prevent the muscles from working properly. As previously stated, lack of Vitamin B will make the muscles weak and flabby, and unable to work effectively. Long drinks of water before a meal will tend to dilute the gastric juice and so retard digestion.

Digestion in the Small Intestine

Here the foodstuffs meet with three juices: that made by the cells of the Intestine, called Intestinal juice; that made by the Pancreas, called Pancreatic juice; and that made by the Liver, called Bile. The last two enter the Intestine by means of a duct. All three juices are essential for the further digestion of the food and the complete breaking down of the foodstuffs, but space does not permit of much detail. Both the liver and the pancreas will be affected if tight clothing is worn. The digested food is propelled in segments along the 20 odd feet of the small Intestine, and is gradually absorbed into the blood stream by means of little projections in the walls of the Intestine. The projections are called Villi, and resemble the pile on velvet. Each villus contains two tiny tubes, one a minute blood vessel which absorbs the digested proteins and sugars, and the other a small lactole which absorbs the emulsified fats. Both these connect with vessels in the walls of the Intestine, which carry the collected materials from all the villi, and discharge them into the main blood stream.

The only means by which the digested foodstuffs can reach the cells of the body is by the blood stream, and therefore it is most important that the circulation and the heart are in good working order. Exercise, rest, and fresh air will help largely in obtaining this. The coils of the intestines are kept in position largely by the abdominal muscles in the walls of the abdomen. These must be taut and strong to prevent sagging, and correct diet and exercise will keep them fit.

The solid waste materials from the food pass into the large intestine, where a large proportion of the water is extracted, and the residue is passed to the rectum for daily excretion. A child should be trained very early into regular habits on this matter, as constipation means that an ideal breeding-ground for germs and bacteria is formed, and the poisons and gases produced by the fermentation of the putrid waste material are absorbed into the blood stream, and causes poisoning of the cells. Constipation is one of the causes of appendicitis.

No study of dietetics is complete unless typical menus are prepared showing the best planning of the family income. This should be worked out on incomes such as the children's parents would receive, and local expenditures for rent, rates, food, etc., should be taken into consideration. The most educational value is obtained when these 'Budgets' are worked out in class, step by step, with discussions.

Budgets and Menus

The total amount of money for food per week for a typical family should be discovered by subtracting all the other legitimate expenses from the total income. This must be planned to provide for the various members food that is suitable, economical, and of the right food value. The entire week's meals for every meal should be planned: this teaches even distribution of money, variety in dishes, the avoidance of waste by using heat wisely for cooking, and using up left-over food.

In a classroom the easiest way to teach the planning of weekly menus is by the use of coloured food models. These can be made very cheaply, and easily, by using the many coloured advertisements of foods that are to be found in all the well-known magazines. These, if cut out and mounted on cardboard, are quite strong enough for the purpose, and with the use of small blocks of wood, with a slit for the insertion of the food model, meals can be set out very quickly. It is much easier for children to discuss the concrete than the abstract, and the models enable them to visualize the menu.

Some interesting work on menus has been done by the British Medical Association recently, and a supplement from their journal, published

25th Nov., 1933, is worth consideration. It is entitled "Nutrition," and costs 1s.

Family Fare, published by the Association of Teachers of Domestic Subjects (price 6d.) is also a useful book, showing the right planning of money and food for various incomes and occupations.

School Lunches

In many of the reorganized Senior Schools, where numbers of children are conveyed from surrounding districts, canteens are provided at the school, where for a few pence daily the children can obtain a hot two-course dinner. This has not become general, and many children still have to bring portable meals to school. It is important that proper accommodation should be provided in order that they may sit down to a table, or desk, covered with a cloth, and eat this meal comfortably, and decently. The school should be equipped with means for warming food brought from home, such as pasties, potatoes, shepherd's pies, puddings, etc. Facilities should be provided also for boiling eggs, warming milk, and making cocoa.

The equipment provided depends upon the number of children staying to dinner. A small single-burner oil stove and a portable galvanized room will be sufficient for a few. Two or three burner oil stoves with ovens, an American range, an electric or gas stove, will be suitable where a number stay, according to the area.

Ingredient	Method
Potato and Cheese Pasty 4 oz. short pastry. 2 large potatoes. 1 oz. cheese. Salt and pepper.	Cook the potatoes and mash well with a little milk, margarine, salt and pepper. Add the grated cheese. Make the pastry and make small pasties using the above as a filling. Bake in a quick oven 20 min.
Egg Pasty 2 eggs. Salt and pepper. ½ oz. margarine. 1 tablespoonful milk. 4 oz. short pastry.	Scramble the eggs with the fat and milk and seasonings. Make the pastry and make into pasties using the egg as filling. A little chopped bacon can be added to make a change.
Fish Pasty Cooked fish, e.g. finnan haddock. Mashed potato. Short pastry. 1 tomato.	Flake fish and mix with mashed potato. Season well. Make the pastry and put in filling with sliced tomato.

FIG. 1

Recipes for Pasties

An oven fitted around the flue pipe leading from a tortoise stove is an excellent, and economical way of warming food.

Cocoa should be well boiled, and is more nourishing if made with skim, or scald milk instead of water. Boiling improves the flavour, and renders it more digestible.

A lesson should be given in school on Portable Dinners. Great stress should be laid on the importance of the midday meal, and that part of the food brought should contain the valuable foodstuff protein. A list of suitable foods, and sandwich fillings should be drawn up with the aid of the class. Where there are facilities for warming food, the teacher should tell the children dishes that are suitable to bring.

Methods of packing up the dinners should be illustrated; where no hot drinks are provided at school, a list of suitable ones to bring in a Thermos Flask should be given. Tea should be discouraged; Cocoa, milk and water, Soup, Bovril, Oxo, or Marmite made with milk or water, Oxo Cubes, hot lemonade, etc., are suitable drinks to bring.

The children should understand that it is just as important that a portable lunch should be as well balanced as any other meal. In addition to the egg, pasty, or sandwich, the meal should include some fresh fruit, or salad, cake or pudding, and a drink. Jelly, or blancmange are easy to carry in a small basin, or cup, and do not entail much work in preparing. Country children do not make full use of salad plants such as lettuce, watercress, mustard and cress, celery, and tomatoes.

The teacher is on delicate ground when discussing with the children the dinners they bring from home. It must be remembered that in many cases they have nothing at all to do with choosing, preparing, and packing the food. No child should be made to feel uncomfortable or awkward because the dinner they have brought is unsuitable, or badly packed. Great tact must be displayed by the teacher. If there is much difficulty over the suitability of the food and packing, it is a good plan to show a series of good portable lunches when there is an open, or

INGREDIENTS	METHOD
1. *Cheese and Tomato Paste* 2 eggs. 4 oz. grated cheese. ½ lb. tomatoes. 2 oz. butter or margarine. Salt and pepper if necessary. *Note.* Some cheese is very highly flavoured.	Pour boiling water over the tomatoes to loosen skins. Remove skins and chop up tomatoes. Grate cheese. Beat up eggs. Melt the fat in a saucepan, add the other ingredients and heat gently, stirring all the time until the mixture thickens. Do not allow to boil. Store in a jar. This paste will keep several days.
2. *Potted Meat* 1 lb. shin of beef. Salt and pepper. Pinch of mixed herbs. A bay leaf. 1 oz. fat.	Remove skin and fat from the meat. Shred the lean finely. Put in a greased stone jam jar. Tie the herbs and bay leaf in muslin and add. Cover with a lid and put in a moderately hot oven and simmer gently about two hours. Pound the meat well. Rub through a sieve. Season well. Put in small basins and cover with melted fat. This paste will keep several days.
3. *Nut and Honey* Chopped nuts. Thick honey.	Chop nuts finely, mix to a stiff paste with honey. The quantity made depends upon the amount of sandwiches to be made. The mixture keeps several days.
Apple and Cheese 1 oz. grated cheese. 1 small apple. 1 tablespoonful salad dressing.	Peel apple and chop finely. Mix with the cheese and dressing. Spread on bread and butter.
Layer Sandwich No. 1 1 egg. Slices of bread and butter. Salt and pepper. ½ oz. margarine. 2 or 3 leaves of lettuce. 1 tablespoonful milk.	Scramble the egg, using the margarine and milk. Spread ½ on a slice of bread and butter. Cover with another slice. Put lettuce on the top and cover with another slice of bread and butter. Spread the other ½ of the scrambled egg on top and cover with a slice of bread and butter. Cut in rectangular blocks.
Layer Sandwich No. 2 2 sardines. 1 oz. cheese. 2 or 3 leaves of lettuce or a little watercress. Slices of bread and butter. Salt and pepper.	Remove tail and backbone from sardines and flake up the flesh. Cut the cheese in thin slices or grate finely. Arrange in layers with bread and butter as above.
Chocolate Filling Grated chocolate. Bread and butter. Chopped nuts.	Grate the chocolate and spread on bread and butter with the chopped nuts.

FIG. 2

Recipes for Sandwich Fillings

parents' day at the school. A short lecturette might be given to the parents by the Head Master or one of the Staff on Portable Dinners, and the facilities provided at school for warming the food, explained.

It is important to encourage variety, and the following recipes for sandwich fillings and pasties will be useful. The children could copy these and take them home. The Domestic Subjects Mistress can co-operate by allowing the girls to prepare these, and other recipes, in the Cookery lesson. In this way the children can taste the mixtures, and if they enjoy them, and realize how easy they are to make, they will be in a better position to either persuade their mothers to make them, or to allow them to do so themselves.

The practical application of all lessons dealing with the child's health is essential. The teaching otherwise becomes pointless and valueless.

School dinners form an admirable way of emphasizing lessons on dietetics, and full use should be made of this opportunity. Many teachers have testified to the fact that scholars who have a good midday meal are more alert and active at afternoon school, than those who have been fed inadequately and unwisely. In other words, "the proof of the pudding is in the eating!"

Conclusion

"A little knowledge is a dangerous thing," and where food is concerned this is very clearly demonstrated. Food faddists are a trial to themselves, and more so to other people. For healthy people a diet consisting of plain food, cooked and served attractively, with variety in the menu, will suffice. Every diet should contain daily some food in its natural raw state. Under this heading come milk, fruit, salads, nuts, etc.

Some useful books of reference for the teacher are—

Food and the Family, by V. H. Mottram (Nisbet).

Food, Health, and Vitamins, by R. H. A. Plimmer and Violet G. Plimmer (Longmans, Green & Co., Ltd.).

The Chemistry of Fresh Foods and their Losses on Cooking, by R. A. McCauee and H. L. Shipp (His Majesty's Stationery Office, 2s. 6d.).

Manual of Modern Cookery, by Jessie Lindsay and V. H. Mottram (University of London Press).

FIRST AID IN SENIOR SCHOOLS

IT is extremely important that children should leave the Senior Schools with some knowledge of how to deal with emergencies which may arise in everyday life. Accidents will happen in home, street, and field. Knowledge of how to act in such circumstances gives assurance, prevents panic, and enables the unfortunate patient to get immediate assistance. It should be noted that the title of this section is *First* Aid with the emphasis on the word *first*. The amount of attention to be given to a patient depends on the time required by a qualified practitioner to arrive on the scene of accident. The longer the period, the more essential it is that the first aid rendered should be effective and competent. The proper practice of first aid depends to some extent on a knowledge of the structure of the human body. Thus there must be a connection in school instruction between lessons in physiology and hygiene.

Even in school life the practice of first aid may be necessary. On the football, rugby, and hockey fields limbs are sometimes broken and players suffer from injury which causes unconsciousness. In the gymnasium and drill classes accidents can easily happen. The writer has had to deal with many cases whose incidence could not be forestalled. One boy, for example, broke his nose whilst playing in a relay team, and another had a long pitch-pine splinter pass through his foot when he was running in stockinged feet to change his shoes. Great care is usually taken by those who teach science to see that accidents are reduced to a minimum. Still emergencies arise, and a knowledge of what to do then is valuable. Swimming is a pleasing exercise, but unfortunately man cannot breathe under water, cramp does attack some, beginners suffer from panic—and so artificial respiration may have to be practised. Teachers should

FIG. 1

St. John Ambulance Association

An excellent way to learn first aid is to join the local cadet division of the St. John Ambulance Association. This photograph was taken at Gravesend encourage their pupils not only to learn to swim but to know how to rescue drowning people and to apply artificial respiration. The Certificate of the National Life Saving Association should be in the proud possession of each "leaver."

The space at our disposal in this section is limited, and no attempt can be made to give a full First Aid course. The ground to be covered is therefore outlined, with some guidance on the method of teaching.

Bleeding

This may well be the first subject for consideration. Physiology lessons will have explained that the blood within the body is carried through a system of blood vessels which can be divided into three classes—

1. The *arteries*, which carry blood from the heart to the various parts of the body.
2. The *veins*, which take the blood to the heart.
3. The *capillaries*, fine, hair-like tubes which link up the veins and arteries.

When damage is done to a blood vessel, it is necessary to know which type of blood vessel is injured. The nature of the bleeding will reveal this—

(*a*) *A cut artery*—blood bright in colour—issues in strong spurts in time with pulse—bleeding occurs from both sides of cut, but mainly from side nearer heart—arteries of any size are rarely injured except with very severe cut, as they lie deep in the limbs—severed arteries are very dangerous, as death from bleeding can ensue within a few minutes unless first aid is *immediately* given.

(*b*) *A cut vein*—blood dark purple in colour—gushes into wound from both sides of cut, mainly from side farther from heart—as the walls of veins are not so thick as arteries the sides tend to collapse at the cut, and this helps to close up the wound.

(*c*) *Damaged capillaries*—as these are small blood vessels it is rarely that bleeding from such is dangerous. We shall discuss the treatment of simple cuts and abrasions later.

CLOTTING OF BLOOD. Bleeding from a wound tends to stop itself because blood exposed to the air begins to clot. It does not clot inside the blood vessels unless these are injured or for other medical reasons. The clotting of blood is brought on by the action of the white corpuscles. If blood did not clot in this way it would be possible to bleed to death from a tiny scratch. The blood clot seals up the damaged opening and so stays the blood wastage. With large cuts, especially in the arteries, the blood flow from the cut is so powerful as to sweep away any blood clots. Therefore first-aid treatment of cuts must be to stop the flow of blood; clots can then form to close up the wound.

ARTERIAL BLEEDING is dangerous, and a doctor should be sent for; meanwhile the bleeding must be stayed by First Aid methods. Where small arteries are damaged, pressure on the cut with a piece of antiseptic dressing will generally stay the blood. Elevation of a damaged limb will also assist. With more extensive injury, bleeding may be stopped by pressing the cut together and pushing against a bone. This is done fairly easily when the injury is to the foot or wrist. In other cases this may not be possible; then the blood stream along the damaged artery must be cut off. This can be done in one of several ways—

1. Pressure on the wound itself as explained above, replacing fingers with pad as soon as possible.
2. Pressure on the artery effected at a point between the injury and the heart. This may be sufficient to slacken the bleeding while a pad is placed over the injury.
3. Application of a tourniquet. Where pressure as indicated above does not stop bleeding, it is then necessary to apply a tourniquet. To do this efficiently the assistance of a second person is required, for one must continue pressure on the wound and raise the affected limb whilst the other must apply the tourniquet. A tourniquet is an appliance for stopping the circulation of the blood by squeezing up the blood vessels. There are several forms used by medical men, but in First Aid treatment a handkerchief loosely knotted and slipped over the limb is a useful form; the handkerchief is tightened up by inserting a stick between the limb and the handkerchief and twisting the stick. The tourniquet must be applied tightly enough to stop the circulation; if too loose it will cause the softer

veins to be compressed and not the arteries, and this will only aggravate the bleeding. A doctor should be summoned as soon as possible, for a tourniquet in position for more than 30 min. may cause permanent injury to the limb.

Pressure Points. Those who wish to know how to render First Aid efficiently should learn from a chart the positions of the arteries and the points at which direct pressure of the artery against a bone may stop arterial bleeding. Such points, for example, are—

In the Head. One running behind ear; the occipital artery pressure is applied two fingers' breadth behind the ear and on a level with the lower margin. A second passes over the middle of the lower jaw and pressure is possible against the jaw-bone. The third is the temporal artery, which passes in front of the ear; the pulse can be felt about ½ in. from the ear-hole.

Trunk. On each side of the lower end of the larynx an artery passes. Pressure is made against the spinal column. The sub-clavian artery passes by the top of the upper rib behind the inner end of the collar bone. Pressure can be made against the rib by a key end padded and pressed down behind the collar bone. This artery can be pressed with one thumb with the thumb of the other hand assisting to give greater pressure.

Limbs. In the arms the brachial artery can be felt pulsating on the inner side of the muscle practically on the line of the stitching of the coat sleeve. Pressure should be made against the bone of the upper arm. There are two arteries in the wrist. The only one where pressure can be easily made is the radial artery that comes near the surface. This is the point where it is usual to feel the pulse.

In the legs, an artery enters from the abdomen in the middle of the groin and pressure should be with both thumbs. In the thigh it is difficult to find pressure points. In the foot one pressure point can be discovered over the middle of the instep and the other at the ankle joint.

The teacher should go over these pressure points. They can be checked from the fact that the pulse beat can be felt quite easily at each point.

Simple Bandages

No First Aid course would be complete without a description of bandages and methods of bandaging. Here we can only give but a brief outline, but the teacher can consult the St. John Ambulance Manuals for fuller instructions.

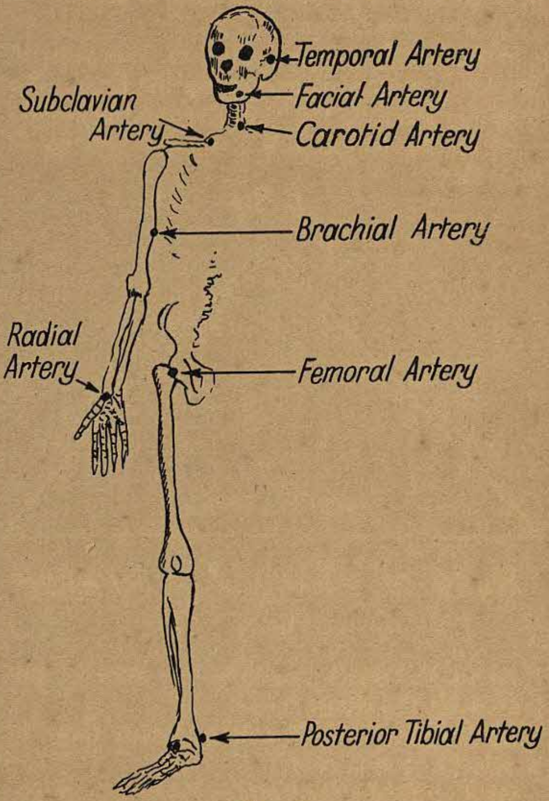


Fig. 2

A Few of the Pressure Points

Bandages may be simply classed as: (*a*) triangular bandages, and (*b*) the roller bandage.

The Triangular Bandage

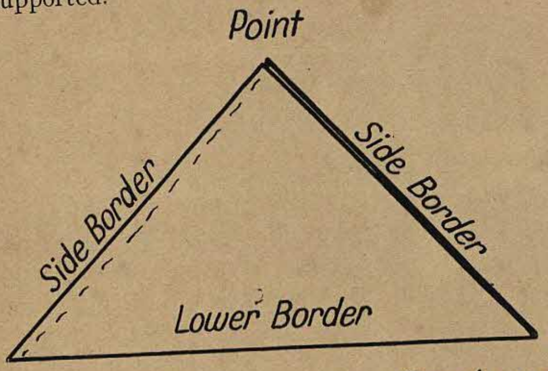
This is essentially a bandage for First Aid. A number of these bandages should be made for practice purposes. They are made from bleached or unbleached cotton or linen, and, as the name signifies, are triangular in shape. One yard of material one yard wide will make two triangular bandages, by folding across one diagonal of the square and cutting along the fold. The diagram will show the names given to the various parts of the bandages; these should be memorized by the children, as descriptions of the use of this type of bandage include these terms.

The uses to which the triangular bandage are put may be summarized as follows—

(1) *For Arm Slings:*

When bones are fractured or the limb is damaged, support is needed by the limb. The weight is taken by the bandage from the neck—

(*a*) In the LARGE ARM SLING the forearm is supported.



Parts of Triangular Bandage.

FIG. 3

(*b*) In the small arm sling the wrist is supported yet the elbow is free.

(*c*) The ST. JOHN SLING is another form, in which the hand is raised.

(2) *For Bandaging Various Parts of the Body:*

Illustrations of the various uses can be seen printed on a triangular bandage that can be purchased from the St. John Ambulance Association, Clerkenwell, E.C.1. (Price 1/–.)

In addition to its use in an open form, the triangular bandage can be folded into a broad or narrow band; the use of either will depend on the extent of the injury. The illustration will show how the folds are made. The method of folding the bandage for storage is also shown.

ROLLER BANDAGES

These are not essentially bandages for First Aid. In schools, however, they are very useful for minor injuries. They are made from several kinds of material—woven cotton, bleached cotton with a loose mesh, linen, gauze, flannel, etc., are all used. Each bandage is usually six yards long and the width varies from one to six inches. The bandages are ready rolled when purchased. The following terms may be noted—

Partly unrolled bandage—Free end is called the tail.
,, ,, ,, Rolled part called the head.
,, ,, ,, Front of bandage is nearest roll.
,, ,, ,, Back of bandage is outer part.

In applying roller bandages it is always *the back* which is applied to the limb or injured part—at least to begin with. Full instructions for using the bandages cannot be given here, but the following points should be kept in mind—

1. The bandage is anchored, or kept firm, by wrapping round and round a limb several times, allowing the bandage to overlap exactly.

2. The end having been anchored, the bandage is then wrapped spirally round the limb in such a way that one turn overlaps by about two-thirds over the layer below.

3. The above method will only give satisfactory results for parts of the body of uniform thickness, e.g. wrist and fingers; with the thigh or upper arm a reversed spiral is necessary. See *St. John Handbook* for particulars, also Fig. 5.

4. When bandage is being applied, only a few inches should be unrolled at a time.

5. Before a bandage is used again it must first be rolled up. Method of rolling up—

(*a*) Fold down two or three inches.

(*b*) Fold again to make tight edge.

(*c*) Hold roll in left hand between thumb and index fingers, use other fingers to keep tight, and roll with right hand.

Broken Bones

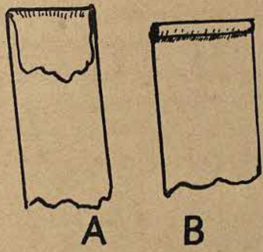
In playground and on sports field bones are sometimes broken, so it is well to teach children something about First Aid treatment. The technical term for a broken bone is a FRACTURE.

TYPES OF FRACTURE—

(*a*) *Simple.* In this type only the bone itself is broken, very little damage being done to the tissue around it.

(*b*) *Compound.* Here the bone is broken and the skin and the tissues are very much damaged; the broken bone, for example, may protrude through the skin and so allow dirt and germs generally to enter the wound.

Here a warning should be given—careless First Aid treatment may cause a simple fracture to become compound by rough movement of the injured limb, or the patient himself may cause the trouble by a wrong movement.



Rolling Roller Bandage

FIG. 4

Several other terms in connection with fractures are used, and these are applied as indicating the injury to the bone.

A green stick fracture is one in which the bone does not break right across but bends and cracks. This type occurs in children, as the bones are more flexible in youth. *A comminuted fracture* is one in which the bone is severed in several places. Great care in First Aid is here needed. When the broken ends are driven into each other an *impacted fracture* is caused. *A complicated fracture* is one in which not only is the bone broken but damage is done to some other organ, e.g. the lung may be pierced, the brain injured, etc.

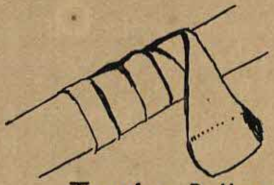
FIRST AID TREATMENT

There are several signs of fracture, local pain, swelling (which may cause the serious fracture to be unrecognized), deformity of limb, and, of course, in a compound fracture the bone can often be seen or felt.

Warning. Unless you are sure of the method of treatment do not attempt to do anything, but get a doctor quickly.

Notes on treatment—the object of this is to prevent an injury from being aggravated.

1. Treat the patient where he is—don't move him to the side of the football field or side-walk. Hold up the traffic if necessary until you have made the limb immovable, and thus safe from further injury. Don't let busy-bodies flurry you.
2. Remember that bleeding must be stopped first before other treatment is given.
3. Remember that there is a shock to the body when a fracture is incurred, so treat the patient for shock (see p. 299).

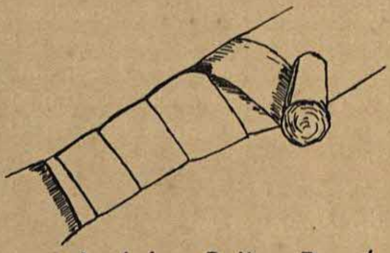


Turning Roller Bandage

FIG. 5

4. If quite sure how to proceed, place limb in natural position, don't let bystanders touch it, apply splints and bandages to keep limb immovable.

Splints are strong but thin pieces of solid material, long enough to fasten a damaged limb so that it cannot move. They should be long enough to keep the joints above and below the damaged part at rest, and should be padded and applied outside the clothes. In emergencies, umbrellas, walking-sticks, broom handles, etc., may be pressed into service.



Applying Roller Bandage

FIG. 6

5. If a leg is damaged and appears to be shortened, it is necessary to straighten it and pull it out to normal length. This must be done carefully by an even, gentle pull, with one hand behind the heel and the other on the instep.

6. Where the spine, thigh, or pelvis is damaged great care is needed, and the patient must be kept in the lying position. A doctor should advise wherever possible, and the First Aid treatment should consist in keeping the patient warm and treating shock.

Other fractures which may occur other than to limbs, spine, and pelvis are—

(*a*) To the skull—broken base shows bleeding at nose and ears.

(*b*) To the jaw.

(*c*) To the ribs—indicated by sharp pain on deep breathing; if lung pierced, frothy and red blood may be spat up.

(*d*) To the collar bone—children often suffer this injury; when falling they put out hand to save themselves and so cause the fracture. Treatment consists in taking off the outer clothing, placing a pad under the armpit, raising the forearm and supporting with St. John sling, and then tying the injured limb with broad bandage round elbow and body to lever the shoulder outward.

(*e*) To the kneecap—with patient propped up and limb elevated and supported, apply long splint from heel to buttock and fasten in position with bandages. Apply other bandage above kneecap, crossing on splint and bringing up and tying below kneecap.

For fuller details see *St. John Handbook.*

The great thing to remember in case of school accidents is not to lose your head, and thus allow further injuries to be done to the patient.

For fractured skull see section on *Unconsciousness.*

Artificial Respiration

First Aid to the drowning is dealt with under "Swimming." Briefly it may be stated that there are three methods—

Shafer's Method—loosen clothing, clear mouth, place patient face downward, support head on one arm, turn sideways to keep nose clear of ground, place yourself astride patient with each hand on lower ribs, thumbs parallel to spine, press forward and relax about fifteen times a minute.

Sylvester's Method—loosen clothing, clear mouth, place patient on back, get assistant to hold tongue, kneel at head, grasp arms, draw up as far above the head as they will go, pause two seconds, force arms back on to ribs, crossing forearms over pit of stomach.

Laborde's Method—for use where arms or ribs are injured—lay patient on back, clear mouth, hold tip of tongue with handkerchief, pull tongue forward and let it go back, repeat movement about fifteen times a minute.

Medical aid, blankets and hot bottles must be obtained. An hour's effort at least must be applied. Whilst one person is endeavouring to restore breathing, others may rub the limbs or apply the hot-water bottles about the patient's body.

Burns and Scalds

BURNS

A burn is an injury to the skin by application of dry heat. The term is also applied to damage by corrosive acids or alkalis. A burn may—

1. Cause only redness of the skin—this is a burn of the first degree and, although painful for a short time, is not serious.
2. Raise blisters; this is a burn of the second degree.
3. Damage the underskin and nerve endings.
4. Destroy the whole of the epidermis over an area. This is serious. In severe burns the tissues may be blackened and charred. Clothing sometimes adheres to the skin and the flesh is often further damaged in removing the clothing.

First Aid treatment should be directed along three lines—

1. *To Alleviate the Burn Itself*

For simple burns rub on soap, treat with carron oil (a mixture of equal parts of linseed oil and limewater), sodawater, vaseline, or powdered starch. With severe burns, a doctor should be summoned, as proper attention can be given only by a qualified medical person. Failing this, treat as follows—

(*a*) Remove clothing; if stuck on, cut round with scissors.

(*b*) Place burnt limb in water at temperature of body (98·4° F.).

(*c*) Dress skin with lint moistened in water at body temperature to which bicarbonate of soda

—1 dessertspoonful to a pint—has been added. Keep moist till doctor arrives.

(*d*) If no water is available, cover with cotton-wool and bandage carefully without undue pressure.

2. *To Treat Shock*

Even with small burns shock may be more dangerous than the burn itself—especially is this the case with young children. Signs of shock are: patient is (*a*) cold, (*b*) pulseless, (*c*) almost motionless, (*d*) breathes very shallowly, (*e*) low in temperature.

Treatment. Keep head lower than feet, well cover up patient, apply hot bottles—if conscious and able to drink, give warm drink of weak tea—massage limbs towards the heart.

3. *To Stop Poisoning*

One of the dangers of severe burning is that poisons made by destruction of the flesh get into the blood stream and lead to general poisoning of the system. Medical attention will endeavour to prevent this. Solutions of picric acid and tannic acid are used for this purpose.

BURNS BY CORROSIVE LIQUIDS

Strong acids and alkalis sometimes cause these in the chemical laboratory.

Treatment

1. Dilute acid or alkali by pouring water over affected part.
2. If an acid, neutralize by strong solution of washing soda.
3. If an alkali, neutralize with vinegar.

If eyes are damaged: (1) wash with water, opening eyelids and pouring freely on eyeballs; (2) neutralize with *weak* solution of soda for acids or boracic acid solution for alkalis.

SCALDS

These give rise to damage similar to that from burns. They arise from moist heat.

Treatment is as for burns, except that no grease should be used if skin is broken. A solution of boracic acid applied on lint is effective.

ACCIDENTS WITH ELECTRICITY

In this electric age it is well to explain the dangers of electricity. A number of children have lost their lives because they have climbed the pylons of the Central Electricity Board and short-circuited the current. Death can easily occur, unless precautions are taken, if an electric current either direct or alternating passes through the body. Generally it can be said that a voltage of over 200 is likely to be fatal. When a person suffers a shock, the victim involuntarily gives a scream, becomes insensible, breathes with a gasp or two, and may at this stage die.

First Aid Treatment

1. Beware of touching the victim if the current is still on. Switch off the current.
2. If this cannot be done, stand on rubber pad, other articles of rubber, or dry clothing. Wear gloves or grasp the victim with material. The danger is that the rescuer may receive shock also.
3. Loosen clothing round neck, etc., treat burns if any, persevere with artificial respiration, send for doctor, give hot coffee or tea when patient regains consciousness and *can swallow.*

ACCIDENTS WITH COAL GAS, ETC.

Several accidents of this kind may occur: (*a*) person in room where gas is turned on, (*b*) car owner in garage with car engine running, (*c*) person overcome from fumes of lime-kiln. In all cases the state of unconsciousness is brought on by breathing carbon-monoxide fumes.

First Aid Treatment

1. Take out into open air—send for doctor, stating nature of accident.
2. Apply artificial respiration.
3. Give stimulants, cold douches of water on chest followed by hot douches, ammonia to nostrils.
4. Massage limbs towards heart to assist circulation.

When entering room full of smoke or gas fumes cover mouth with damp handkerchief, keep low and quickly remove patient. Beware of using naked light.

In connection with the use of gas and electricity, teach children to take proper precautions. Emphasize the importance of good fittings in all cases. Poor electrical and gas fittings and those put in by incompetent persons lead to accidents.

Poisons

Any substance which, if taken in sufficient quantities, can cause death may be termed a poison. Whenever a person has taken poison a doctor should be summoned at once by a message telling him what has happened. Poisons may be divided into three classes, according to their effect on the body. These classes are—

1. CORROSIVES

As the name suggests, these poisons destroy the tissues of the body by burning or corroding; such poisons are strong mineral acids, such as sulphuric and hydrochloric acids, and strong alkalis such as caustic soda and potash.

Symptoms. Lips and mouth burned; breathing difficult; retching; severe burning pain in throat, mouth, and abdomen; vomiting, mucous and blood in vomit; collapse.

First Aid Treatment

1. Neutralize poison—

(*a*) For acid give alkali, e.g. lime water, chalk and water, or one teaspoonful of bicarbonate of soda, whitening, chalk, or plaster in a tumbler of water.

(*b*) For alkali give acid, e.g. lemon juice or vinegar with citric or tartaric acids in weak solution, equal quantities of water.

2. Relieve pain and soothe injured tissues by giving olive oil, salad oil, liquid paraffin, or egg and milk.

3. Apply hot bottles to body. If breathing is difficult, apply hot flannels to throat.

2. IRRITANTS

Here again the name suggests the effect of this group of poisons. The tissues are irritated and not destroyed. Examples of irritant poisons are fungi and berries of various kinds, decomposed food, salts of various metals such as arsenic, mercury, and copper salts.

SYMPTOMS. These vary, but there is a burning sensation in mouth, stomach, etc., but no apparent destruction of tissue. Retching, colic, and diarrhoea also occur.

Treatment

1. Give emetic—*unless* lips and mouth are burned. This induces sickness and gets rid of the poison from the stomach.

Useful Emetics: (*a*) Mustard, 1 tablespoon in 1 tumbler of warm water. (*b*) Salt, 2 tablespoons in 1 tumbler of warm water. (*c*) Alum (powdered), 2 tablespoons in 1 tumbler of warm water. Repeat emetic at intervals of five minutes till vomiting occurs. Encourage vomiting by tickling throat. When vomiting commences, give draughts of warm water to encourage it.

2. Give antidote if known (strong tea is useful).

3. Give castor oil, soothing food or drink, e.g. raw eggs and milk, gruel, cornflour.

4. Treat patient for shock.

Poisoning in schools is not likely to occur very often. Warn children of danger of chemicals used in science. Give lessons on poisonous berries and fungus.

3. NARCOTICS

These are poisons which act on the nervous system, including brain, and induce either—

(*a*) Sleep ending in coma; pupils of eyes become pin points; pulse slow; breathing deep—opium is one of the drugs that cause this effect.

(*b*) Convulsions.

(*c*) Delirium and unconsciousness.

Treatment

1. For (*a*) keep patient awake by walking him up and down, giving strong coffee or tea, and throwing cold water over chest, neck, and head. For (*b*) give emetic: artificial respiration should be applied between convulsions. Most deadly poisons cause these symptoms.

2. Follow with emulsives, milk, and eggs, etc.

3. Treat shock.

A list of poisons, symptoms, and treatment should be hung in the school.

POISONS CHART

Simple poisons and their treatment—

1. Acids . . Hydrochloric and sulphuric, etc.	Give water whilst preparing solution of washing soda, chalk and water, magnesia and soapy water. Follow with olive oil, milk and eggs. Avoid shock.
2. Alcohol . .	Emetic, then stimulant. Keep body warm.

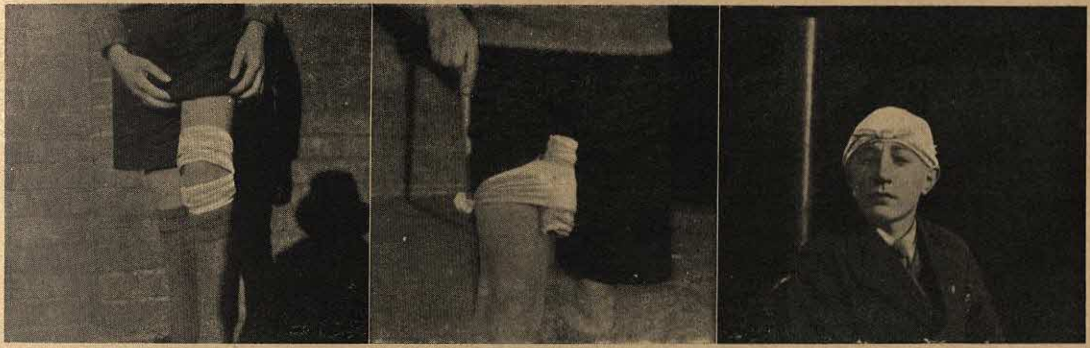
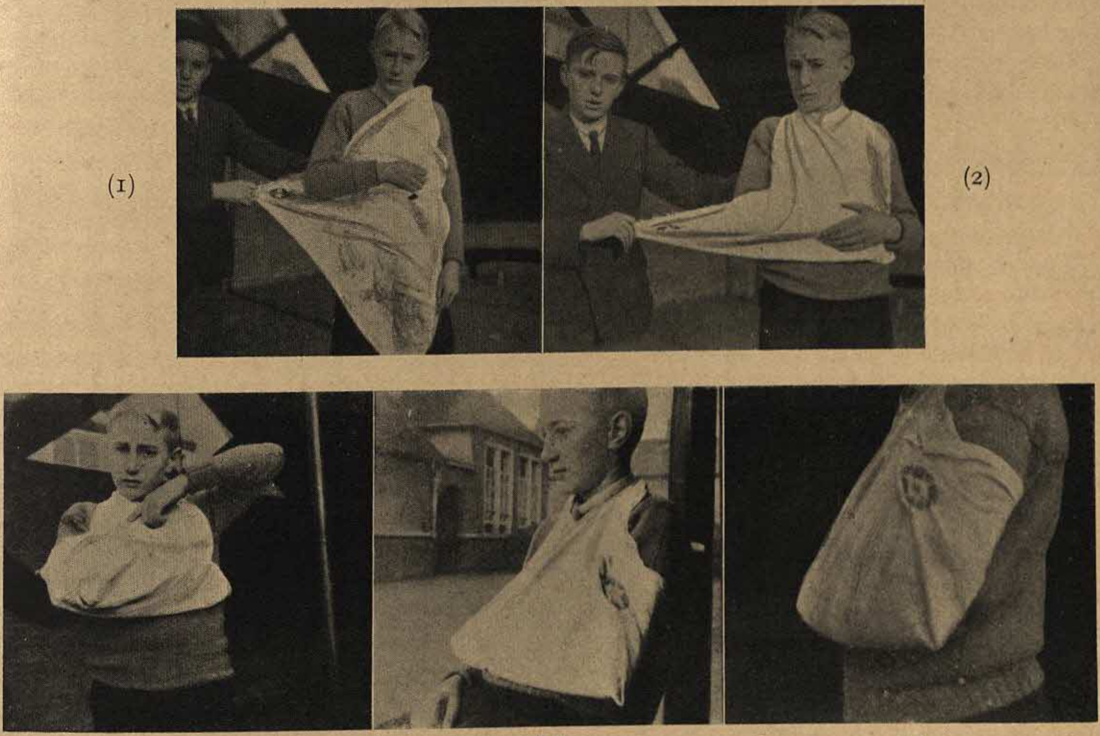


Figure of eight bandage on leg *Showing method of applying tourniquet* *Triangular bandage applied to head*

FIG. 7

Bandaging



(1) (2)

(3) (4) (5)

(1) *First position.* (2) *Second position.* (3) *Completing sling.* (4) *and* (5) *Side views*

FIG. 8

Large Arm Sling

3. Arsenic	Emetic if vomiting; warm water, hot bottles, etc., to stomach; keep flat; let patient suck ice.
4. Poisonous berries.	Emetic, castor oil, hot bath.
5. Camphorated oil.	Emetic, warm application to stomach, coffee, Epsom's salts.
6. Carbolic acid	Epsom's salts in water, white of egg in water, hot application to abdomen.
7. Carbon dioxide	Take patient into fresh air, loosen clothing, apply artificial respiration, later apply warmth and give stimulants.
8. Coal gas	Fresh air and oxygen if possible. Keep patient flat.
9. Poisoning from bad fish.	Emetics.

Unconsciousness

Frequently children faint in school and a few words on the question of unconsciousness are necessary.

Simple fainting fit, which will be the most frequent case needing First Aid treatment in school, is caused by a momentary insufficiency of blood to the brain.

CAUSES OF FAINTING FIT

1. Stagnation of air in room, e.g. children in "close" hall.
2. Over-exertion, e.g. at sports, etc., especially in hot weather.
3. Standing for a long period, e.g. in the case of child returned to school after illness.
4. Lack of food.
5. Loss of blood.
6. Emotional shock, good or bad news, seeing accident, etc.

Symptoms. Pallor, patient staggers or clutches at support, eyelids tremble, pulse weakens, breathing shallows, sinking feeling in stomach, noise in ears, sight blurred, the patient falls unless supported, and lies limp, with cold and clammy skin.

Treatment. Lie patient on back in open space, loosen clothing, cover to keep warm, apply smelling salts, bathe face and temples with cold water.

On return to consciousness, keep patient for a time in recumbent position, give sal volatile when able to drink, let patient rest on recovery. When patient feels a fainting fit coming on, it can often be stopped by making him sit down and bending his head forward between his knees. This encourages the flow of the blood to the brain.

Other forms of unconsciousness are caused by—

INJURIES TO THE HEAD

(*a*) *Concussion*

Symptoms. Unconscious only short time, pale or blue colour in face, pulse weak, often quick and irregular, breathing shallow.

First Aid Treatment. Give fresh air, lie in prone position, send for doctor, keep body warm, apply cold compress to head; complete rest in a darkened room is necessary and activities must only be resumed after doctor's advice.

(*b*) *Compression of Brain*

More serious than concussion, external marks of injury often seen, bone fragment or blood clot may be pressing on brain. Face flushed, pulse full but slow, breathing stentorous, blood may issue from nose and ears, pupil of one eye dilated more than other, temperature raised, symptoms very often develop gradually.

Treatment. Get doctor as soon as possible, keep body warm, flat, and in sheltered spot.

SUNSTROKE

Caused by exposure of head, neck, and spine to fierce sunlight, or heatstroke (which is very similar in results) may occur from heat in tropical climate, factory, or stokehole.

Put patient in cool, shaded spot, keep air moving by fanning, apply cold water to neck, head, and spine. Send for doctor.

EPILEPTIC FIT

Symptoms. A teacher may be faced by a case of a child falling in an epileptic fit. The symptoms are a sudden fall often with a scream, then convulsions of body and limbs, rolling eyeballs, tongue may be bitten in convulsions.

Note that patients who suffer from these attacks often have a warning by a bodily sensation, head noises or the like.

Treatment. This consists in prevention of injury to the patient; move out of danger from striking furniture, etc., put something soft under head, do not restrain movement of limbs, place cork, stick pencil, or similar hard substance, wrapped in handkerchief, as gag between teeth; loosen clothing round neck; if patient vomits move head on one side so that substance is not drawn into lungs; when fit is over, encourage patient to rest; consult doctor on after-treatment.

HYSTERIA

This is really a nervous disorder and occurs most frequently in young girls. As a result of mental excitement the patient seems to lose control of herself; she laughs, cries, throws herself about, grinds her teeth, and generally acts out of control.

Treatment. In hysteria a firm attitude must be adopted towards the patient; order her to be quiet, tell her you will throw cold water over her if she doesn't desist, then sprinkle with cold water.

Minor Injuries

Children fall in the playground, and scrape off skin or cut themselves in handwork lessons. Simple First Aid treatment can be rendered, often by the children themselves or by monitors under guidance.

MINOR CUTS AND SCRAPES

Treatment—

(*a*) Remove clothing from wound if necessary.

(*b*) Remove any scraps of grit, etc., from wound.

(*c*) Wash wound with sterilized water; this can be water which has been boiled and allowed to cool.

(*d*) Paint tincture of iodine on wound and skin around.

(*e*) Put pad of gauze or dressing on and bind up.

Don't touch wound with fingers.

BRUISES

These are caused by blows, which cause the small blood vessels to rupture. Some parts of the body bruise more easily than others.

Treatment. Bathe with cold water, apply cold compress, which is simply a wet pad, and keep moist. Later, massage and give hot fomentations. Instead of cold water as first application, equal parts of spirit and water on the cold compress are very effective. A cold wet pad on a "black eye" is the best First Aid treatment. The pad should be renewed as the pad becomes near to the temperature of the body.

STINGS

Bee Sting. Extract sting—wash with bicarbonate of soda, salt, soda, sal volatile, or ammonia—if sting is in mouth, wash mouth out with bicarbonate—send for doctor if swelling in mouth.

FIG. 9

First Aid for Girls

Girls from Christchurch Senior School who formed the 1st St. John Ambulance Cadets in Chatham

Wasp Sting. No sting left generally—treat as above—if swelling persists consult doctor, as the sting of a wasp is often contaminated and introduces septic matter.

Insect Bites. Bathe in vinegar, potassium permanganate solution, or as above. Apply zinc ointment to sting.

Teaching First Aid in Schools

This may be done in several ways—

1. By establishing A SPECIAL CLASS, either in conjunction with school scouts or guides or independently in school or leisure time.

2. IN CONJUNCTION WITH LESSONS in physiology and health instruction. This is a very good method. The different sections will then be taught as the appropriate lessons on the body are taken.

The Skeleton. First Aid treatment of fractures, making use and application of splints.

The Circulatory System. Bleeding, pressure points, simple bandaging.

The Respiratory System. Artificial respiration.

The Nervous System. Unconsciousness, effects of poisons, fainting fits, etc.

Treatment of Minor Injuries may be taught quite early in the school curriculum, so that every child understands methods of simple treatment.

3. DRAMATIC WORK. The Police and St. John Ambulance Society stage competitions in which accidents are supposed to happen and the competing teams have to say what they would do and show what bandaging, etc., would be applied.

Great fun and a great deal of instruction can be given in this way at school. The children enter into the spirit of the thing.

Patients in motor and cycle accidents, or those found in rooms full of gas, etc., act their part well. One amusing contest set recently consisted in allowing the teams to find a patient unconscious from poisoning. Now before proper treatment could be given, it was necessary to find the poison. The competition took place in a wood, and though the teams looked everywhere they did not locate the poison bottle under some dead leaves. At the end of three minutes nothing was found, and the doctor in charge of the contest said, "The patient is dead."

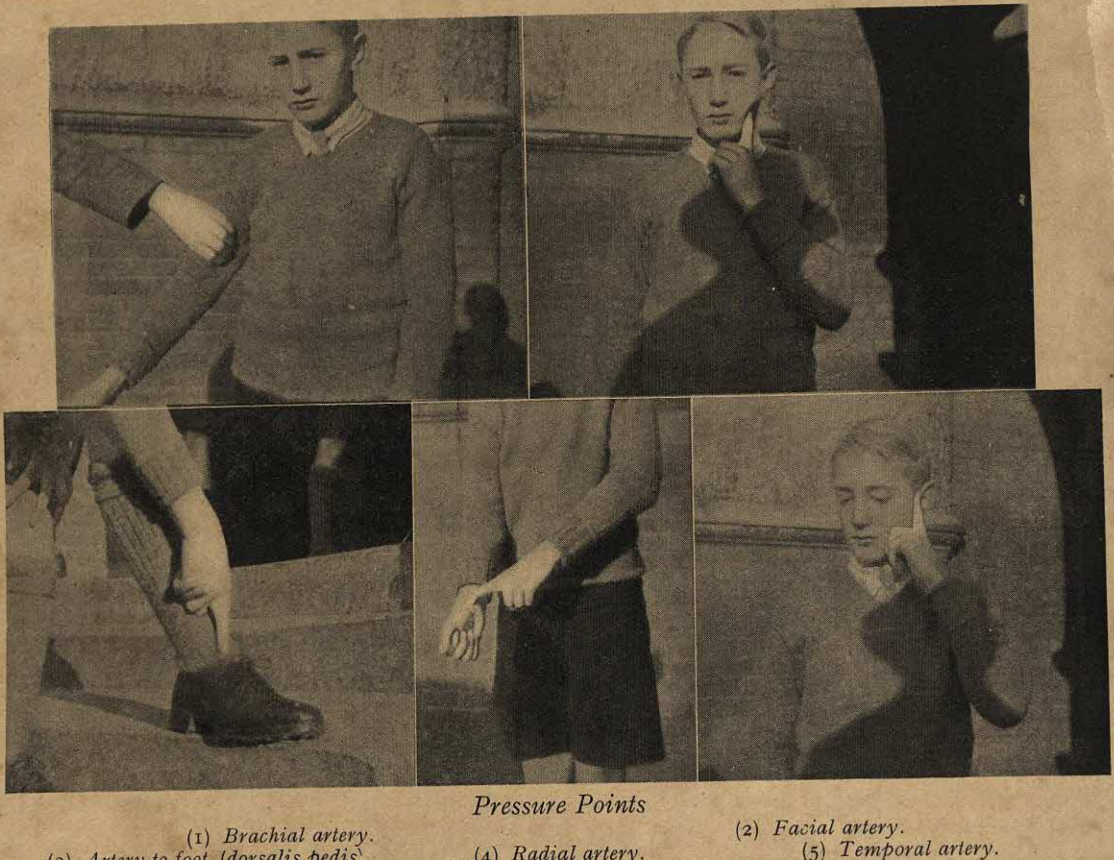
For practice in learning pressure points to stop arterial bleeding, etc., the class should be paired. Each one of the pair acts in turn as the patient and the rescuer.

First Aid Outfits for Schools

For use in accidents the following should be kept in a closed box accessible to all, and as material is used it should be replenished.

Pair of clean scissors.
Boracic lint, 1 yd.
Absorbent cotton-wool ½ lb.
Oiled silk, 1 yd.
Sterilized gauze, 3 pkts.
Roller bandages, 1 doz. from 1 in. to 4 in.
Castor oil, 2 oz.
Tin of Mustard.
Eye bath.
Triangular bandages, 4.
These should be kept in an air-tight box.
Clinical thermometer.
Bottle of smelling salts.
6 simple splints.
4 oz. tincture of iodine.
4 oz. boracic powder.
4 oz. permanganate of Potash.
Boracic vaseline, 4 oz.
Friars balsam, 2 oz.
Syringe.

For class work, triangular bandages, splints, and roller bandages will be required according to the size of class.



Pressure Points

(1) *Brachial artery.* (2) *Facial artery.*
(3) *Artery to foot (dorsalis pedis).* (4) *Radial artery.* (5) *Temporal artery.*